European Commission

Study on good practices for reducing road safety risks caused by road user distractions

Final report

Written by TRL, TNO, Rapp Trans
October – 2015

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EXECUTIVE SUMMARY

Background to the study

The European Commission has a specific interest in understanding road safety risks associated with road users who are distracted and inattentive as a result of using technology. Understanding this topic will help to support an important policy objective of the European Commission – that of identifying road safety risks (so that appropriate measures can be taken).

In this study, TRL, TNO and Rapp Trans undertook a number of tasks to answer the following research questions:

- What is the nature and size of the distraction problem in road safety in the EU?
- Which approaches and countermeasures have been used to reduce the road injury burden of distraction?
- Which 'best practice' approaches should be used by EU states in their efforts to reduce the road injury burden of distraction (including an assessment of costs and benefits)?

Overall conclusions

Nature and size of the problem

1. There is no standard definition of distraction used in the road safety literature or by practitioners. There is also a lack of standardisation of collision and injury data across the EU, and a lack of information on the proliferation of technologies and their use in traffic. This makes it impossible to quantify with any real certainty the extent of the problem of distraction in road collisions across the EU. A common definition and common approach to coding distraction in collisions is needed.
2. The current estimate for the impact of road user distraction on accidents in the EU is that it is a contributory factor in around 10-30% of road accidents. Current limitations mean that this estimate of distraction related accidents across Europe currently lacks validity and reliability until supported by coordinated data collection.
3. There are a large number of technological developments (17 were identified in the project) that have the potential to have an impact on distraction. There is a lack of objective data on their impact, but based on expert judgement throughout the project a number of consensus findings emerged:
    - Many new technologies have the potential to either increase or reduce distraction, with the level and direction of impact often determined by the way in which the technology is implemented. If poorly implemented, most technologies (even those which are intended to benefit road safety) have the potential to do harm, by increasing road user distraction. The importance of good HMI design was highlighted in all stakeholder and expert engagements, and in the opinion of the project team is a key consideration for future countermeasures.
    - Combinations of technologies might be used to cancel out drawbacks of individual technologies, or to enhance benefits.

- Even for those technologies which seem most promising in terms of reducing distraction (for example partial automation systems which take driving tasks away from the driver) there is a perceived risk among experts that drivers may find ways to use the spare attentional capacity this presents on non-driving related tasks, resulting in possible issues with situation awareness.
- It is anticipated that many new technologies will generally have the greatest impact on levels of distraction (increased or reduced) in motor vehicle drivers. However, some will potentially impact on distraction in other road users groups (for example technologies that reduce the need to interact visually with nomadic devices such as smartphones). All road users will benefit from reduced distraction in other groups, as this will result in them having less risk of being involved in accidents with distracted third parties.

Countermeasures

4. Technologies that are designed (or can be used) to reduce distraction can be thought of as operating either through real-time prevention, real time mitigation, or warning of collisions. Automated driving systems will also provide an important future impact on distraction; however until they are mature and proper research has been undertaken to understand their limitations (for example handing back of control to drivers), distraction prevention and mitigation measures are preferred. An additional consideration however is that while collision warning systems are 'later in the process' of a potential crash, the technologies involved are more mature, and therefore of considerable value in the short term.
5. In terms of countermeasures that can be used to address the problem with distraction, when considering all of the data gathered in the project the key findings were:
    - Legislation, certification, public awareness campaigns and education during the licensing acquisition process (as well as for professional drivers) were seen as the most effective non-technology-based approaches. Awareness campaigns (and education during licensing) should be delivered at the national level, but using a standard EU-led approach.
    - The most promising technologies are voice recognition, biometry, head up displays, artificial intelligence, and (especially from researcher feedback) vehicle automation. Standardised HMI design (for technologies) should also be an important component of an EU-wide approach to distraction.

Best practice approaches

6. The final multi-criteria analysis (based on inputs from all other tasks) concluded that in terms of costs and benefits, the most promising approaches to dealing with distraction are:
    - Collision warning systems (forward collision warning and lane departure warning). These particularly score high on impact and user acceptance, while maturity of technology is high.
    - Education about distraction during driver licence acquisition (and for professional drivers)

Recommendations

The nine recommendations from the project are split below into four categories. These are recommendations related to data, technologies, awareness and education, and standards. In all cases, our assessment is that such recommendations would be cost beneficial. Suggestions are made for who should take each recommendation forward, and how.

Data

1. The literature review and review of statistical publications, and stakeholder interviews, confirmed that there is a need for a common definition of distraction, and the related concept of (in)attention. The project team suggests that the following definitions from Engström et al. (2013) are adopted by the EC:

   - **Driver inattention:** "…inattention occurs when the driver's allocation of resources to activities does not match the demands of activities required for the control of safety margins." (Engström et al., 2013, p38).
   - **Driver distraction:** "…where the driver allocates resources to a non-safety critical activity while the resources allocated to activities critical for safe driving do not match the demands of these activities." (Engström et al., 2013, p35).
   - **Activities critical for safe driving:** "…those activities required for the control of safety margins…" (Engström et al., 2013, p17).

   It should further be noted that this definition of distraction should be adopted in a way that makes it clear to those using it that it is device-independent, and mode independent (if 'driver' is replaced by 'road users'); instead, it is focused on the tasks people may undertake which lead to distraction.

2. There is also a need for standardised data to be collected on distraction in accident databases across the EU (utilising the definitions above as their basis) so that comparisons across countries can be made on the basis of the same underlying factors. To be able to accurately determine the effects of distraction it will be necessary for countries to begin reporting and investigating distraction in road traffic accidents if they are not already doing so, ideally in a standardised format. Therefore a standard approach to contributory and causal factors involving distraction should be adopted.

   One way in which this could be achieved is for the EC to promote the variable 'Distracted by device' in the Common Accident Data Set (CADaS) from 'Low' to 'High' importance. Additionally, we recommend that the EC considers adding a separate data field to state the extent to which distraction contributed to an accident. Although these types of data are difficult to collect in an objective way, the increasing proliferation of mobile devices that may cause distraction makes it more important that good data are available to track the issue.

   Finally, the EC could build its efforts to encourage member states to include such information in national reporting into the CARE database, and could publish clear annual data on the prevalence of distraction in accidents across EU Member States who are reporting such data.

3. Standardised estimates on the proliferation and use in traffic of distraction-increasing (and reducing) technologies should be undertaken across the EU. Again this will aid in drawing cross-country comparisons. Such measurements would need to be undertaken regularly (ideally annually) and could be run in a similar way to the CARE database, with the EC coordinating and Member States providing data.

Technologies

4. Systems that operate far in advance of collisions (distraction prevention measures such as phone blocking systems and distraction mitigation measures such as distraction warning systems) are preferred to systems that present warnings regarding impending collisions; however the latter technologies are more mature, and have greater supporting evidence for effectiveness (despite not being solely focused on distraction), making them a better short term alternative for policy focus.

   Collision warning systems (such as forward collision warning and lane departure warning) are already being covered in Euro NCAP testing procedures. This is to be welcomed, since these particularly score high on impact and user acceptance in the current study. We recommend that the EC monitors the deployment of such systems so that these data can be used (in combination with monitoring regarding proliferation of distracting technologies, and distraction in accidents) to keep appraising the size of the distraction problem in the EU.

Awareness and education

5. The EC could promote the adoption by Member States of best practices developed in the CAST project on how to effectively design, run and evaluate awareness campaigns. This would provide a benchmark for campaign effectiveness and stimulate the exchange of knowledge and experience on awareness campaigns between Member States. With the EC being a driving force behind Member State campaigns through the exchange of experiences with different campaigns and sharing of good practice, this would nonetheless allow campaign messages to be adapted to culture and language. Any campaigns should include distraction in non-motorised road users.
6. Member States should be encouraged to include distraction content in their driver licensing programmes, and in any training required for professional drivers.

Standards

7. The market of smartphone operating systems is dominated by Apple and Google, both of which have developed technology to use smartphone in vehicles more safely by using the vehicle’s HMI features to control the device: Android Auto and Apple CarPlay. Google Android also has some built-in features to limit distraction while driving, notably the (standard) option to respond to incoming phone calls with an automated text reply when moving. Clearly Apple and Google recognise their responsibility in limiting road user distraction. If these companies can be persuaded to adopt common guidelines to further reduce road user distraction this would be a powerful and pragmatic way to reduce road user distraction globally (this could be achieved by signing an MoU to adopt the ESoP).

   The trilateral (Japan, US, EU) group on human factors could provide a good platform to initiate such an initiative. If this approach does not lead to voluntary adoption by the industry within an acceptable timeframe (and distraction by nomadic devices still is an issue) then legislative approaches could be taken (for example through EC electronics certification of nomadic devices).
8. A standard interface for secure mounting and powering of nomadic devices on a central position of vehicle dashboards could limit such distractions such as those caused by sliding and dropping devices and entanglement of power cords. If broadly adopted such a standard would also facilitate enforcement of handheld calling/texting bans. Considering the broad recognition of the importance of distraction in road safety the EC could request industry to establish and adopt such a standard on a voluntary basis, and consider legislative action only if insufficient progress is made.
9. Nomadic devices are often used for navigation or traffic information by car drivers. CAN-bus data would allow developers of automotive apps to develop safer, less distracting apps (for example better switching between day/night view, vehicle type identification to prevent that navigation intended for passenger cars is used in trucks, navigation in tunnels, and so-on). The EC could request the C-ITS Platform to determine what data should be made available on the CAN-bus for nomadic devices.

Additional findings and considerations

One additional finding from the research could be described as falling outside of the specific scope (as define by the research questions).

In short, there is a need for further research into various aspects of road user distraction. Although the importance of road user distraction as a cause for accidents is broadly recognised, the scientific basis for policies to combat distraction is small. This is in part due to the nature of the topic; accidents are exceptional events and research data are by definition sparse. But a better understanding of the processes behind distraction is important for the development of European and Member State policies dealing with distraction. In particular little is known on distraction that can be induced by the automation of specific driving tasks. In 2010 the US/EU Bilateral ITS Technical Task Force listed the 10 most important research needs. The EC could request the now trilateral group to update the list with the latest insights and use it as a basis for setting the research agenda on road user distraction. On the basis of the findings in this project, the following areas should also be targeted by research:

- Voice recognition: How should such systems be designed?
- Night vision: Can such systems present extra information to drivers in such a way as to alert the driver to potential risks, but without being too distracting?
- Biometry: Can systems spot inattention quickly enough to permit useful intervention or alerts? Can they be reliably enough to avoid drivers wanting to turn the systems off (e.g. false alarms)?
- Legislation of usage conditions: How should legislation be designed and worded with the pace of technology development (e.g. new input and output modes) being so quick?
- Public information campaigns: What is needed in such campaigns beyond the provision of information? How can behavioural change techniques help?
- Auditory/vocal (cognitive) distraction and how it relates to driver performance and crash risk.
- Sociological aspects of distraction: What makes drivers willing to take part in distraction activities? How do social norms play a role? Does the need for ‘connectedness outweigh risks in the perception of drivers?
- Views of young drivers on driving and distraction: What makes young drivers particularly susceptible to distraction by devices? Which sub-groups of young drivers are particularly at risk?
- Effects of countermeasures: Which countermeasures can be shown to really work? What are the relative benefits of enforcement approaches? Can behaviour change approaches work to reduce exposure to distraction?
- Pedestrian distraction studies: What is the exposure of pedestrians to distraction? What behaviours other than crossing the road are affected? How does the increased risk for pedestrians (per unit of travel) compare with that of other road users?
- Distraction/alertness in the transition to automated driving: How long do people need to move from a distracting task to taking over control of an automated vehicle? What are the best ways of alerting drivers in this situation?
- Self-regulation of road users and good driving behaviour: Does behavioural adaptation (e.g. reduced speed) actually reduce risk for some distracting tasks? What are the distraction tasks that cannot benefit from behavioural adaptation?
- Future trends and challenges in distraction: Does the ageing population represent an increased distraction risk? Will ‘wearable technology’ improve the situation or make things worse?
- New vehicles and distraction: Will new vehicles with different behavioural profiles (e.g. electric bicycles with higher speeds) reduce distraction-related safety margins?
- Business models and eco systems of new distraction-preventing technologies: How can countermeasures be built into the business case? Who will pay for distraction-reducing technologies?

RÉSUME ANALYTIQUE

L'information et les opinions présentés dans ce projet sont ceux des auteurs, et ne sont pas nécessairement en accord avec ceux de la Commission. De même, la commission ne garantit pas l'exactitude des données utilisées durant le projet. Aucune personne, qu'elle soit de la commission ou agissant en tant que représentant de la commission, ne peut être tenue responsable concernant la future utilisation de l'information présentée dans le rapport ci-dessous.

Contexte

Il est dans l'intérêt de la commission européenne de mieux comprendre les dangers associées avec les conducteurs qui sont distrait et inattentif au volant dû à l'emploi d'appareils technologiques. Mieux comprendre le problème de la distraction au volant est un stade important afin de pouvoir atteindre un des objectifs de la commission européenne : mieux comprendre les dangers de la route (afin de pouvoir développer les interventions les plus appropriés pour réduire ces risques).

Pour ce projet, TRL, TNO et Rapp Trans, on entreprit une série d'intervention afin de pouvoir répondre aux questions suivantes :

- Quelle est l'ampleur du problème causé par la distraction au volant sur les routes de l'Union Européenne (UE)?
- Qu'elles stratégies et mesures de prévention ont était utilisées afin de réduire le nombre d'accident causées par des conducteurs distraits?
- Qu'elle(s) approche(s) devrai(en)t être utilisée(s) par les membres de UE afin de les aider à réduire le phénomène de la distraction au volant?

Conclusions

Ampleur du problème

1. Il semblerait qu'il n'y ait pas de définition commune concernant la distraction au volant, que ce soit dans les études scientifiques concernant la sécurité routière ou dans le milieu professionnel. De même, il y a un manque d'uniformité vis-à-vis des données obtenues dans les rapports d'accidents ainsi qu'un manque d'information concernant la prolifération des technologies et leur utilisation sur la route. Ce manque d'uniformité signifie qu'il est impossible de mesurer l'ampleur du problème causé par la distraction au volant à travers l'UE. Il est donc impératif d'établir une définition commune ainsi qu'une méthode commune de rapporter la présence d'une activité susceptible d'avoir distrait le conducteur dans les rapports d'accident.
2. Il semblerait que la distraction au volant joue un rôle dans environ 10 à 30% des accidents de la route. Cependant à cause des limitations concernant l'uniformité et la validité des rapports d'accidents ces résultats doivent être considérer avec prudence. En effet, en attendant la mise en place d'une méthode commune pour rapporter la présence d'une activité pouvant distraire le conducteur il est impossible de mesurer de façon valide l'ampleur du problème.
3. Il semblerait qu'un nombre d'appareils technologiques pourraient être source de distraction (17 sources ont été identifiées). Bien qu'il y ait un manque de certitude concernant leurs effets vis-à-vis des conducteurs, cette étude a néanmoins put établir un nombre de consensus concernant leur impacts :
   - Ces nouvelles technologies peuvent augmenter ou réduire le niveau de distraction. L'efficacité de chaque appareils dépend de la manière dont ils sont mis-en place. S'ils sont mal introduits il y a de fortes chances qu'ils augmentent le niveau de distraction provoquant une détérioration de la qualité de conduite. En effet, les discussions avec les parties prenantes et experts ont mis en évidence l'importance

qu'il faut accorder au développement des interfaces intégrées. L'équipe de recherche partage cette opinion et suggère que ces systèmes doivent être considérés lors du développement de future mesure de prévention.

- Une combinaison de différentes technologies pourraient être utilisées afin de supprimer les effets négatifs, ou au contraire accroitre les effets positifs to chaque outil.
- Même les outils développer dans le but de réduire le niveau de distraction (en supprimant certaine tâches qu'un conducteur doit lui-même entreprendre) ne sont pas sans risques. De nombreux experts pensent qu'en réduisant les taches secondaires qui doivent être effectuées lors de la conduite, de nombreux conducteurs utiliseront leur ressources cognitive supplémentaire pour effectuer d'autres tâches qui n'ont aucun rapport avec la conduite elle-même, impactant leur qualité de conduite.
- Il semblerait que les automobilistes soit le groupe le plus affectés par le développement et l'implémentation de ces nouvelles technologies, que ce soit de manière positives ou négatives. Néanmoins, certaines technologies pourraient avoir un impact sur d'autres types d'usagers de la route (par exemple des outils qui supprime le besoin d'interagir avec des appareils nomades, comme des smartphones). Cependant, il est clair qu'en réduisant le niveau de distraction pour un type d'usager l'intégralité du réseau routiers en bénéficiera, car cela réduira le risque d'être victime d'un accident de la route causée par un conducteurs distraits.

Méthode de prévention

4. Les appareils visant à réduire les niveaux de distraction au volant fonctionne soit en tant que prévention en temps-réel, d'atténuation en temps-réel ou en tant qu'alerte de collision potentielle. De même, le développement de futurs systèmes automatiques auront surement un impact sur les niveaux de distractions. Cependant, en attendant que des études enquêtant les faiblesses et limites de ces systèmes soient effectuées il est préférable d'utiliser des outils de prévention et d'atténuation. De plus, tandis que les systèmes d'alerte de collision ont tendance à intervenir en dernier lors du processus de prévention d'accident, il semblerait que ces systèmes d'intervention soient les plus testés et devraient donc être considères dans le court terme.
5. Concernant les méthodes de prévention qui ont été utilisées afin d'adresser le problème de la distraction au volants, les conclusions suivantes on était déduites:
   - Il semblerait que les meilleures techniques traditionnelles (soit non-technologiques) en terme d'efficacité serait : la législation, la certification de appareils, les campagnes publicitaires et les informations donnés aux conducteurs lorsqu'ils apprennent à conduire (y compris pour les conducteurs de véhicules utilitaires). Les campagnes de prévention doivent être menée de façon identique à un niveau national, ainsi que dans le cadre de standard imposé à un niveau européen.
   - Les technologies avec le plus de promesse sont : la reconnaissance vocale, biométrie, les affichages tête haute, intelligence artificielle et les véhicules automatique. Un objectif important pour minimiser l'impact de la distraction au volant serait de développer une interface intégrée standard à toute l'UE.

Meilleures types d'intervention

6. A partir de l'analyse coût avantage entreprise pour la dernière analyse multicritère (se basant sur les résultats de toutes les interventions) il semblerait que la meilleure façon d'approcher le problème de la distraction au volant seraient:
   - Des systèmes d'alerte de collision (pour collision frontal et sorties de la voie de conduite). En effet ces systèmes d'alertes sont les plus testés et sont particulièrement bien reçues par les usagers de la route.

- L'intégration d'information à propos des effets de la distraction au volant durant les heures d'écoles de conduites avant l'obtention du permis (y compris pour les conducteurs de véhicules utilitaires)

Recommandations

Les neuf recommandations résultant de cette étude sont présentées ci-dessous. Elles peuvent être regroupées en quatre groupes : Données, technologies, sensibilisation et information et standards. De même, des recommandations supplémentaires concernant la manière dont ces suggestions devraient être mise en place ainsi que les parties qui devraient être responsable pour leurs mises en place fournies.

Donnees

1. La revue bibliographique ainsi que les interviews avec les parties prenantes ont confirmés qu'il y avait une demande et un besoin pour une définition commune du phénomène de distraction, ainsi que les termes liés à l'attention et l'inattention. L'équipe de recherche propose que les définitions suivantes soit adoptées par la commission européenne (les définitions sont basées sur celle fourni par Engström et al, 2013):

   - **Inattention au volant**: Quand l'allocation de ressources cognitive pour une certaine activité est insuffisante pour accomplir cette activité de manière sûre (en maintenant les marges de securite)
   - **Distraction au volant**: Quand l'attention d'un conducteur est divisée entre les activités indispensable à une conduite sans danger et une tache secondaire sans rapport à la conduite, de manières a ce que la quantité de ressource cognitive attribuée à la conduite est insuffisante pour une conduite sans danger.
   - **Activités essentielles pour une conduite sans danger**: Les activités requises afin de maintenir les marges de sécurité

   De plus, il est important de noter que cette définition de distraction au volant est valable indépendamment du mode de transport, et se concentre plutôt sur les activités effectuées qui conduisent à la distraction.

2. Il est nécessaire d'établir un guide commun concernant les données qui doivent être relevés lors d'un accident, qui peut être applicable à travers l'UE afin de pouvoir standardiser les bases de données. Ceci permettra de comparer l'ampleur et les causes du phénomène de distraction au volant à travers l'UE de manière valide. De plus, afin d'établir de manière sûre les facteurs contribuant à la distraction au volant il serait avantageux que tout pays de l'UE rapporte de manière systématique la présence d'activité susceptible d'avoir distrait le conducteur, et ce de manière uniforme à travers l'UE.

   Ceci pourrait être réalisée en promouvant l'importance d'une des catégorie du CADaS (Common Accident Data Set) 'Distraction by device' de 'Low' a 'High'. De plus, nous suggérons que la commission européenne ajoute une catégorie supplémentaire dans les rapports d'accident concernant la contribution relative de la distraction. Malgré le fait qu'il peut être difficile de collecter ce genre de données de manière objective, la prolifération des appareils nomades capable d'être sources de distraction reflète le besoin de développer une meilleure méthodologie afin de pouvoir accéder a des données plus valide.

3. Il serait avantageux d'avoir accès a des estimations standardisés concernant la prolifération et l'utilisation d'appareils pouvant augmenter (ou réduire) les niveaux de distraction au volant, permettant de faire des comparaisons valide entre pays. Afin de fournir des données de haute qualité un tel processus pourrait être réalise en suivant un procédé similaire à celui utiliser pour la base de données CARE, où les états membres fournissent les données en étant supervise par la commission Européenne. De plus ce processus devrait être entrepris de façon régulière, de préférence une fois par an.

Technologies

4. Des systèmes qui fonctionnent de manière à prévenir les conducteurs bien en avance de potentielles collisions (système de préventions empêchant les conducteurs d'utiliser leurs téléphones ou des systèmes d'alerte mesurant les niveaux de distraction) sont plus favorables que les systèmes de préventions qui alertent le conducteur seulement en cas de collisions imminentes. Cependant, ce dernier type de systèmes est plus avancé et semble avoir plus d'évidence scientifique confirmant son efficacité. Par conséquent, a court termes, ces systèmes pourrait être des solutions efficaces.

   Les systèmes d'alerte de collision (pour collision frontal et sorties de la voie de conduite) sont déjà bien établis grâce aux standards Euro NCAP. Ces systèmes sont particulièrement efficaces et bien reçus par les conducteurs. Il serait avantageux que la Commission Européenne contrôle le déploiement de ces systèmes afin de pouvoir estimer de manière systématique l'ampleur du phénomène de la distraction au volant.

Sensibilisation et information

5. La Commission Européenne devrait promouvoir l'adoption des recommandations développées lors du projet CAST concernant les meilleures façons de mener et mesurer l'efficacité d'une campagne de sensibilisation. Ceci permettrai d'avoir une référence de base pour évaluer l'efficacité de chaque campagne, ainsi qu'une opportunité pour les états membres de partager leur connaissances et réflexion entre eux. De plus, étant donné que la commission européenne serait une des forces majeures encourageant cette uniformité, cela permettrai d'adapter ces campagnes de façon à ce qu'elles correspondent au diverse culture présente a travers l'union européenne.
6. La commission doit encouragés ces états membres à introduire d'avantage d'information concernant la distraction au volant dans les programmes enseigner lors des heures d'école de conduite (que ce soit avant l'obtention du permis de conduire ou pour les conducteurs de véhicules utilitaires).

Standards

7. Le marché des smartphones est dominé par Apple est Google, tous deux ayant développé des technologies permettant aux conducteurs de se servir de leur smartphones de façon plus sûre en se servant des système intelligent intégrés au véhicules pour contrôlés les appareils (ex : Android Auto et Apple CarPlay). Par exemple, Google Android a développé des systèmes intégrés qui réduisent les niveaux de distraction durant la conduite (Ex : si un appel est reçu lorsque le véhicule est mobile, le smartphone envoie un message automatique permettant au conducteur de continuer sa conduite sans devoir répondre au téléphone). Ces deux compagnies sont conscientes qu'elles doivent minimiser l'ampleur de la distraction au volant. Pour cette raison, il serait très avantageux que ces compagnies adoptent des objectifs et standards similaires concernant la distraction au volant.

   Le groupe trilatéral (Japon, Etats Unis, EU) serait le mieux place pour inciter cette initiative, encourageant les compagnies d'adopter de tels standards de manière volontaire. Cependant, s'il s'avérait que cette méthode n'entraine pas des changements pour le mieux, et ce dans des délai acceptable (et que la distraction au volant causée par des technologies nomades reste un facteur important de risque d'accidents) des mesure législatives doivent être adopter (par exemple en imposant des standards de certification électronique pour les technologies nomades commune a l'UE).
8. Le développement d'une interface située au centre du véhicule permettant de placer et recharger ces technologies nomades pourrait être efficace pour réduire les niveaux de distraction (e: réduisant les chances de faire tomber ces appareils, l'entortillement

de câbles…). De même ceci faciliterais la répression de l'utilisation des téléphones a la main, que ce soit pour des appels ou des messages textes. Une fois de plus il serait plus avantageux que les compagnies adoptent ces standard de manière volontaire, et que la commission impose des nouvelles législations uniquement si la suggestion précédentes s'avérait être inefficace.

9. Les appareils nomades sont souvent utilises comme outils de navigation ou pour obtenir des informations sur le trafic en temps réel. Les données de CAN-bus permettrait au développeur d'application de créer des Apps plus sures et moins distrayantes (changer du mode nuit a jour de manière plus consistante, navigation dans des tunnels…). La commission européenne pourrait charger la Platform C-ITS de déterminer quelle donnée concernant les appareils nomades devrait etre disponible sur CAN-bus.

Conclusions et observations supplémentaires

Un certain nombre de résultats ne répondent pas directement aux objectifs de cette étude, mais sont tout de même important à considérer et sont donc présenté ci-dessous.

Il est nécessaire d'accroitre la quantité de recherche dans le domaine de la distraction au volant. Les études actuellement disponible montrent que la distraction au volant est un phénomène reconnu et une cause importante des accidents de la route, cependant il y a un manque d'évidence scientifique permettant de développer des lois pour lutter contre ce phénomène. Ceci est un parti dû à la nature du sujet même. En effet les accidents de la route sont des évènements rares, et en conséquence l'obtention de données peut être limitée. Cependant afin de développer des lois au niveau Européen visant à répondre au phénomène de la distraction au volant, il est nécessaire de mieux comprendre les facteurs qui peuvent entrainer la distraction. A présent, il y a un manque de connaissance concernant l'impact des systèmes automatique sur les niveaux de distraction. En 2010 le 'Bilateral ITS Technical Task force' entre le Royaume Uni et les Etats Unis a identifié les 10 domaines de recherche nécessitant le plus d'attention. Le groupe étant aujourd'hui devenue trilatérales, la Commission Européenne devrait demander une mise à jour de cette liste, prenons en compte les avancées scientifiques récentes, et s'en servir pour établir l'échéancier de recherche concernant la distraction au volant. Suite aux données présentés dans cette étude, les recherches futures doivent considérer les domaines de recherche présentés ci-dessous:

- Reconnaissance vocale: De quelle façon devrait-on développer ces systèmes?
- Vision nocturnes: Est-ce que ces systèmes sont capables de fournir d'avantage d'information aux conducteurs, de façon à les alerter de risque potentielles, sans créer d'avantage de distraction?
- Biométrie: Est-ce que ces systèmes sont capables de repérer l'inattention d'un conducteur de manière rapide, afin de pouvoir fournir des alertes de façon opportune? Ainsi que de manière fiable (ex : fausse alerte), afin d'assurer que les conducteurs maintienne ces systèmes engagés?
- Lois sur les conditions d'utilisation: De quelle façon doit-on rédigé les lois concernant l'utilisation de ces systèmes afin qu'elles prennent en compte la vitesse avec laquelle les avancées technologiques se déroulent?
- Campagne de sensibilisation: Mis à part la provision d'information, quel sont les éléments importants à inclure dans ce type de d'interventions? Quels sont les avantages d'utiliser des stratégies comportementales?
- Quelle est l'impact de la distraction auditive sur la qualité de conduite et le risque d'être impliqué dans un accident de la route?
- Aspects social de la distraction: Quels facteurs incite les conducteurs à effectuer ces actions distrayantes? Quel est l'impact des normes sociales? Est-ce que les conducteurs d'aujourd'hui perçoivent le besoin d'être connecter comme étant plus important que les risques associés avec leur comportement?

- Le point de vue des jeunes conducteurs vis-à-vis de la distraction au volant: Quels sont les facteurs qui font que les jeunes conducteurs sont particulièrement susceptible au phénomène de distraction au volant? Parmi ce groupe de conducteurs y-a-t-il des groupes sociaux qui sont particulièrement vulnérables aux effets de la distraction?
- Impact des méthodes de préventions: Quelle méthode de préventions ont était prouver comme étant véritablement efficace? Quels sont les avantages des méthodes de répression?
- Etudes sur la distraction des piétons: Quels sont les risques de distraction pour les piétons? Quels comportements sont affectés, autres que traverser la route? Comment est-ce que cette augmentation des comportements à risque ce compare-t-elle aux autres usagers de la route?
- Niveau de distraction pendant la transition vers la conduite automatique: Combien de temps faut-il pour qu'un conducteur distrait reprenne le control d'un véhicule automatique? Quelle est la meilleure façon d'alerter un conducteur dans cette situation
- Usagers de la route et qualité de conduite: Est-il vrai que dans certains cas, adapter sa méthode de conduite pourrait réduire les effets de la distraction (ex : réduire sa vitesse de conduite) ? Quels comportement distrayant ne semble pas bénéficier d'une adaptation de sa méthode de conduite?
- Futures tendances et barrières à surmonter: Est-ce que le risque de distraction au volant risque de devenir plus prononcer à cause d'une population vieillissante? Est-ce que le développement de future technologies (ex: smart-watches, google-glasses) réduiront les risques causés par le phénomène de distraction ou on contraire les empireront?
- Nouveau véhicule: Est-ce que le développement de nouveau mode de transport avec différentes caractéristique (ex: vélo électrique pouvant aller a des vitesses plus élevées) pourrait réduire les marges de sécurité vis-à-vis de la distraction au volant?
- Modèle d'entreprise pour le développement de nouveau système pour minimiser la distraction au volant: De quelle façon peut-on développer des méthodes de prévention dans les modèle d'entreprise? Qui sera responsable pour le financement de nouvelles technologies visant à réduire le niveau de distraction au volant?

ABSTRACT

This project examined the nature and size of the distraction problem in road safety in the EU (especially in terms of mobile devices), and those countermeasures which can be used to lower its impact. A literature review, a review of statistical publications on national road injury data, a stakeholder survey, interviews and workshops, a review of technology developments and a multi-criteria analysis were undertaken. The study concluded that 10-30% of road accidents in the EU could have distraction as a contributory factor, although limitations of the data available mean this figure requires further validation (partly due to the lack of a commonly agreed and used definition and approach to data coding). A large number of technology developments were identified that have the chance to impact on the issue, both in terms of underlying technologies in future mobile devices, and in terms of vehicle safety systems. Nine recommendations are provided, in terms of data requirements (and common definitions), technology, awareness and education, and standards; these recommendations were based on the multi-criteria analysis of costs and benefits. Further areas for research are also suggested.

ABSTRAIT

Le but de ce projet était d'investiguer l'ampleur de l'impact causes par la distraction au volant sur la sécurité routière a travers l'Union européenne, ainsi que les méthodes de prévention qui peuvent être utiliser pour minimiser cet impact. Ce projet consista d'un nombre d'intervention comprenant : ne revue bibliographique, une revue des bases de données nationale concernant les accidents de la route, des questionnaires, interview et ateliers avec les parties-prenantes, une analyses des avancées technologiques ainsi qu'une analyse multicritère. Il semblerait que la distraction au volant joue un rôle dans environ 10 à 30% des accidents de la route a travers l'union européenne. Cependant, un nombre de limitations (tel le manque d'uniformité dans les rapports d'accident a travers l'Union Européenne) font que ces chiffres doivent être considère avec prudence. Un grand nombre d'avancées technologiques ont-était identifiées qui pourrait jouer un rôle important vis-à-vis de ce phénomène, que ce soit au niveau des systèmes de sécurité des véhicules même ou du développement de future appareils nomades. Neuf recommandations, regroupées en fonction des besoins concernant les données, les technologies, la sensibilisation et les informations ainsi que les standards nécessaires sont présentées dans ce projet. Ces recommandations sont dérivés des résultats de l'analyse cout avantage entrepris durant l'analyse multicritère. De plus, des suggestions concernant d'autres domaines de recherche nécessitant d'avantage d'attention sont aussi présentées.

CONTENTS

1. INTRODUCTION

Increased understanding of crashes and risks is a policy objective of the European Commission[1]. Of specific interest is the increased concern with road safety risk associated with road users who are distracted and inattentive as a result of using technology.

1.1. Aim

The aim of this project was to improve the understanding of distraction in road users and its relationship with road safety and new technology, within the legislative context across the EU.

1.2. Overall objective

The overall objective for the study was to answer the following research questions:

- What is the nature and size of the distraction problem in road safety in the EU?
- Which approaches and countermeasures have been used to reduce the road injury burden of distraction?
- Which 'best practice' approaches should be used by EU states in their efforts to reduce the road injury burden of distraction (including an assessment of costs and benefits)?

1.3. Overview of project structure

The project was divided into nine tasks. This report is the final deliverable (Task 9). It describes the methods used throughout the project, and the final set of findings and recommendations. A breakdown of the tasks (and corresponding sections in this report) is given below:

Task 1 and Task 2 focus on quantifying the problem of accident risk due to road user distraction. This is achieved by reviewing the literature on road user distraction (Section 2) and by reviewing the proliferation of technological developments likely to have an impact on road user distraction (Section 3).

Tasks 3 and 4 (Section 4) focus on potential countermeasures to distraction (including both technical devices and policy actions), by engaging with stakeholders and Member States, and by undertaking reviews of the literature.

Task 5 (Section 5) combines the output from previous tasks to produce the potential costs and benefits of countermeasures. This is achieved through consideration of 'deployment scenarios' taking into account barriers and incentives for deployment, and various costs and benefits.

Task 6 covers the stakeholder consultation aspect of the project, including two stakeholder workshops that have informed the other tasks; results from these workshops are reported throughout the report where appropriate.

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[1] Communication from the Commission: Towards a European road safety area: policy orientations on road safety 2011-2020, COM(2010)389

http://ec.europa.eu/transport/road_safety/pdf/road_safety_citizen/road_safety_citizen_100924_en.pdf

Tasks 7, 8 and 9 were reporting tasks.

Figure 1 illustrates the connections and dependencies between these tasks.

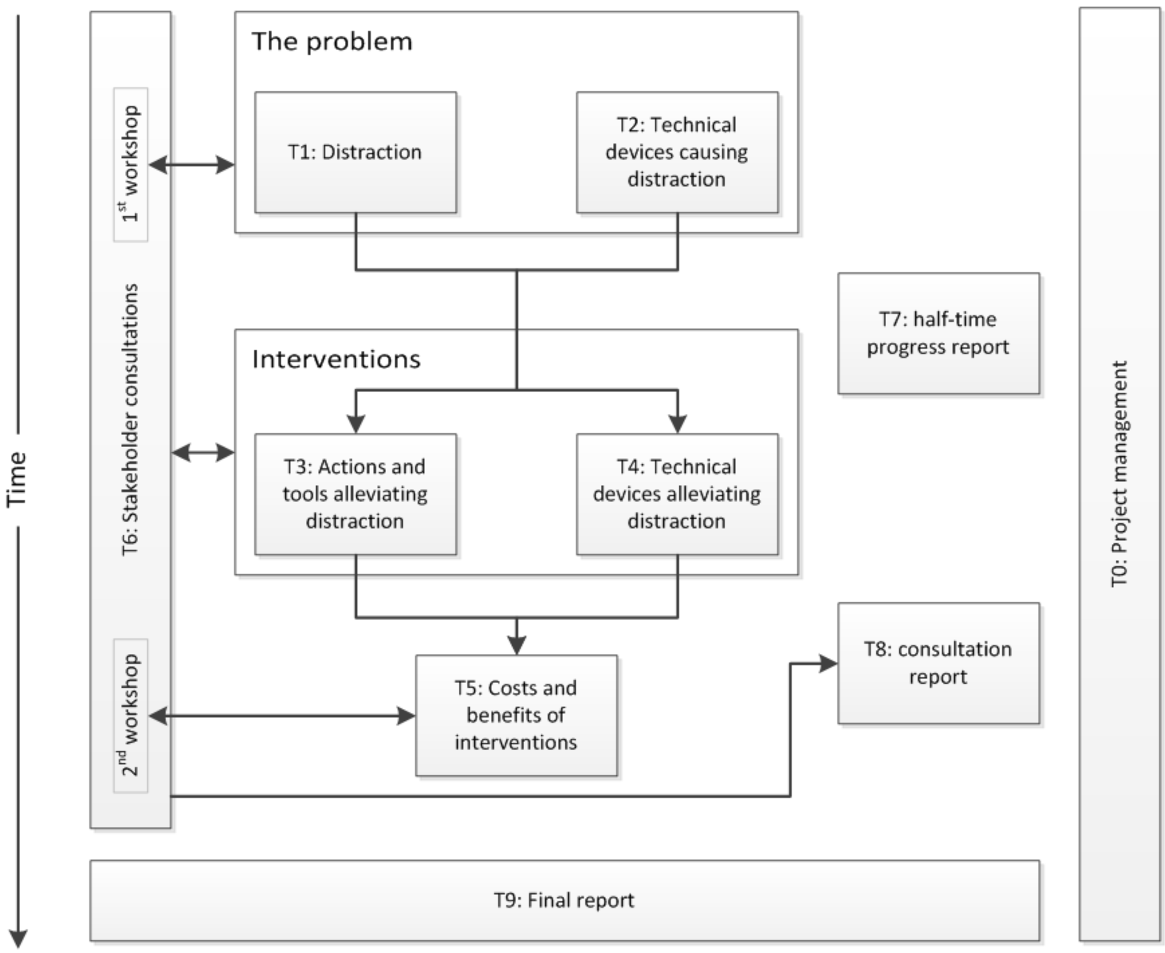


Figure 1: Overview of project tasks

2. UNDERSTANDING DRIVER DISTRACTION AND THE SIZE AND NATURE OF THE PROBLEM – EVIDENCE AND DATA

2.1. Aim

This chapter provides a background to understanding road user distraction and appraises the available statistical and accident data publications from across the EU to understand the impact of road user distraction on casualty risk.

A review of common definitions of distraction and the related concept of inattention along with relevant theoretical background is presented to provide a context for the remainder of the report. Reviews of the literature and of accident data publications are then presented to appraise and estimate the size and nature of the problem in the EU. The methodology and findings from these reviews are described in Sections 2.2, 2.3, and 2.4.

A summary of the findings from this chapter is presented in Section 2.5.

2.2. Review of literature and statistical and accident data publications - methodology

The following steps were undertaken to develop the body of literature from which to define and conceptualise distraction, and assess its impact in the EU.

1. Known published and unpublished literature was compiled from across the project partners.
2. An informal literature search using internet search engines (i.e. Google, Google Scholar and Bing) was performed between September and November 2014 to explore ‘grey’ (i.e. unpublished or soon-to-be-published) literature. This was particularly relevant to permit the investigation of distraction-related accident data throughout the EU.

   The informal search used the following search terms:

   - driver distraction reports
   - European distracted driving reports
   - distracted driving statistics
   - distracted road users
   - mobile phone road safety
   - road user distraction
   - road accident distraction
   - distracted driving [followed by the name of each EU country in turn, e.g. “distracted driving Austria” etc.]

   This search revealed 23 reports containing information on driver distraction and figures for road accidents involving driver distraction. Sources of information such as fact sheets and websites were also found.
3. Search terms for the formal literature search (to complement rather than duplicate existing EU publications) were defined and agreed by the project team and The Commission. The search terms used are detailed in Table 1.
4. A literature search was conducted by an Information Scientist at TRL’s dedicated Library and Information Centre. Due to the large number of publications in this domain, it was agreed that the search would be limited to articles published between

January 2004 and November 2014 (when the search was conducted). The initial search returned approximately 450 abstracts, including some duplicates.

Table 1: Terms for Task 1 literature search

Primary Terms	AND	AND
Distract* OR	Driver OR	Crash OR
Inattent* OR	Pedestrian OR	Collision OR
Attent*	Cyclist OR	Prevent* OR
	Motorcyclist OR	Risk OR
	Children OR	Technology OR
	"Vulnerable road user"	Smartphone OR
		Phone OR
		Mobile phone OR
		Statistic* OR
		Data

5. All abstracts were reviewed to determine whether they met the following inclusion criteria:

   Inclusion criteria for literature on distraction

   - All literature studying the following specific road user groups:
     - Young and novice drivers
     - Older adult drivers (e.g. 'the elderly')
     - Pedestrians
     - Cyclists
     - Motorcyclists
     - Professional drivers (e.g. HGV, bus, taxi etc.)
   - All reviews or theoretical or experimental studies that may aid the definition and conceptualisation of road user distraction or inattention
   - All reported studies of distraction published since 2013 (that may not therefore be included in general reviews of the topic area)

   Inclusion criteria for statistical and accident data publications

   - Any publication or analysis of road user collision data from EU countries in which distraction or inattention is mentioned.

6. Full text articles that met the inclusion criteria and minimum quality criteria (graded as A or B (and C for outcome measures only)) were obtained. The quality criteria can be seen in Table 2.

Table 2: Quality criteria

Grade	Outcome measures	Controls	Analysis
A	Recorded accidents	Adequate methods (e.g. control groups) or statistical procedures (e.g. multivariate modelling) to control confounding variables and bias	Appropriate statistical methods to state confidence limits of statistical significance of any effects found
B	Self-reported accidents	Incomplete control of confounding variables or bias but some attempt made	Inappropriate or no statistical methods used, but some attempt to assess the likely confidence limits or significance of effects
C	Observed risk-related behaviour or self-reported measures with reliable link to accident risk (e.g. attitudes)	No controls	No attempt made to address this
D	Self-reported data with no reliable link to accident risk (e.g. 'I enjoyed the course') or not measured appropriately		

In total, 105 full text articles and two books were obtained for the review.

7. Following the searches, road safety experts in each EU member country (as of November 2014) plus experts in Israel and Serbia were contacted directly. Information on their national police accident report forms, any reports on national accident figures, and any studies on driver distraction-related accidents (such as mobile phone use) in their country were requested.

   Information was received from 16 of these contacts and was used to identify if distraction was recorded on their national police forms or identified in national reports.

8. The European road accident database (CARE) was also investigated to determine the prevalence of the recording of distraction in accidents across Europe.

   Another potential source of distraction data is from in-depth accident databases. In Europe, these include the UK's Road Accident In Depth Studies (RAIDS), Germany's German In-depth Accident Study (GIDAS) and a European in-depth accident database collected as part of the SafetyNet study. For each of these the relevant owners of the data were contacted and where possible bespoke analyses or access to the data to carry out new analysis was requested.

2.3. Background: distraction in driving

Distraction within the context of road safety has primarily been associated with one particular type of road user (vehicle drivers). There are several reasons for this. Driving a motorised vehicle is complex, often fast-paced and places high attentional demands on a human cognitive system which can be thought of as having limited processing capacity. Being distracted, or more precisely not paying full attention to activities required for safe driving when in control of a motor vehicle, can lead to a processing failure resulting in loss of control, putting the driver and other road users in physical danger.

Car drivers also represent the majority of road users across Europe; while they do not have the relatively high injury rates per kilometre driven or per vehicle seen in motorcyclists and cyclists, they are the group of road users who present the greatest injury burden from distraction-related collisions, due to the number of cars on the road.

Traditionally there has been little research with regard to non-motorists such as pedestrians and cyclists being distracted when using the road. This has changed somewhat with the advent of mobile technologies, initially in response to devices such as portable music players, but more so in recent years in response to mobile- and smart-phones. Distraction relating to motorcyclists has similarly been relatively neglected, although again, new technologies afford the possibility of distraction affecting safety for this road user group.

Since the vast majority of the literature relates to distraction for drivers (primarily car drivers) this review will initially focus on this group (Section 2.3.1). The review will present a brief background to the distraction literature, summarising key findings within this domain, with a focus on those most relevant to technology use. Literature seeking to define distraction and recently-developed taxonomies will then be presented so that drivers' use of new technologies can be better understood (Sections 2.3.2 to 2.3.6). Following this, the literature found for other road user groups will be discussed (Section 2.3.7).

Following a summary of the literature reviewed, the most relevant definition and taxonomy of distraction are recommended for use in the remainder of the project (Section 2.5.3).

2.3.1. Distraction: The story so far

Prior to the advent of mobile technologies sources of distraction when driving traditionally included passengers, eating, drinking, roadside advertising, smoking and tuning the radio (Stutts et al., 2003). While the distracting effects of these tasks on safety were of concern, the distracting effects of technology use while driving are considered to be greater than most other forms of distraction (Griffin, Huisingh & McGwin, 2014). The distracting effect of mobile electronic devices on driving and their impact on safety has been investigated for some time now (Brookhuis, de Vries & de Waard, 1991; Stevens & Minton, 2001).

Depending on whether one refers to national crash databases or naturalistic studies, the reported size of the effect of distraction on crash risk can vary considerably (Klauer et al., 2006; Fitch et al., 2013). A frequently-cited odds ratio suggests that phone use while driving is associated with a fourfold increase in crash risk (Redelmeier & Tibshirani, 1997; McEvoy et al., 2005). Understanding the variation in reported figures for distraction-related crash risk requires consideration of the definitions of distraction used when collecting the data (the primary focus of the remainder of Task 1.1) and an appreciation of how secondary activities affect driver performance.

Simulator and test-track studies have shown that drivers reduce their speed when talking on a mobile phone while driving (Haigney, Taylor & Westerman, 2000; Rakauskas, Gugerty & Ward, 2004; Strayer, Drews & Johnston, 2003; Strayer, Drews & Crouch, 2006). Controlled experimental studies also indicate that mobile phone use while driving increases reaction times to potential hazards (Burns et al., 2002; Horrey, Lesch & Garabet, 2009; Caird, Willness, Steel & Scialfa, 2008), decreases the driver's visual scanning of the environment (Engström, Johannson & Ostlund, 2005) and results in poorer lane discipline (Reed & Robbins, 2008). In addition, simulation studies suggest that pedestrians and cyclists are similarly affected when using a mobile electronic device, showing poorer peripheral attention to the environment (de Waard et al., 2014; White, Mwakalonge & Siuhi, 2014).

Although experimental research has shown that phone conversations impair driving performance it is difficult to quantify the risk of this impairment because the reference is usually to 'normal' driving without using a phone. 'Worse than normal driving' does not necessarily equate to increased collision risk. In one study that sought to benchmark the effects of using a mobile phone while driving, Burns et al. (2002) compared the impairment caused by using a hands-free and hand-held mobile phone with driving with a blood-alcohol concentration at the UK legal drink drive limit (80mg of alcohol per 100ml of blood – a level related to crash involvement). This simulator study found that certain aspects of driving performance were impaired more by having a mobile phone conversation (hands-free or hand-held) than by having this blood alcohol level. Results showed a clear trend for significantly poorer driving performance (speed control and choice response time to different road signs) when engaged with a mobile phone conversation. The best performance was for normal driving without having any phone conversation.

On their own, simulator and controlled track studies paint a fairly clear and consistent picture with regard to the performance decrement that secondary task performance (particularly the use of a mobile electronic device) has on road user performance. A research synthesis of multiple research methodologies (e.g. simulator, epidemiological, and naturalistic studies) by Caird, Johnston, Willness & Asbridge (2014) has concluded that text messaging while driving increases crash risk and adversely affects driving performance. Reed, Hallett, Cynk and Jenkins (2014) however note that the relationship between texting while driving and crash risk may not be so clear cut. Similarly, the picture for conversing on a mobile phone is not so straight forward when other research approaches are considered; no single methodology paints the full picture of the effect of mobile phone use on crash risk (Caird et al., 2014). For example, naturalistic studies (and some case-crossover studies) report that specifically talking or listening on a mobile phone is not associated with increased crash risk to the extent that simulator and controlled track studies might suggest (Fitch et al., 2013; Klauer et al., 2014; Hickman & Hanowski, 2012; Olsen et al., 2009; Victor et al., 2014).

Fitch and Hanowski (2011), using the same naturalistic driving data as Olson et al. (2009), report that HGV drivers use their mobile phones less often during high task-demand driving conditions than they do during low-task-demand driving conditions, suggesting that drivers self-regulate their mobile phone use to the demand of the driving task. In simulation studies, drivers do not necessarily have the option of when to engage and disengage with the task; this may explain the difference in findings between naturalistic and laboratory studies. In addition, the finding that drivers reduce their speed and increase their following distance when talking on a mobile phone while driving suggests that drivers are offsetting at least some of the extra cognitive demand required for the phone conversation (Caird et al., 2014; Young, Regan & Lee, 2009). Drivers also appear to dump or reduce other tasks such as checking mirrors and instruments when conversing on a mobile phone while driving (Brookhuis et al., 1991). Such behavioural adaptation is congruent with recent models of driver behaviour and suggests that drivers are managing demand in order to maintain a comfortable safety margin or feeling of task difficulty (Fuller, 2011; Summala, 2005, 2007).

In a further naturalistic study, Sayer et al. (2007) found that light-vehicle drivers improved their ability to maintain a constant speed when using a mobile phone while driving and maintained their eyes on the forward roadway more. Similarly, it is further reported that analysis of data from the naturalistic 100-Car Study found that drivers looked at the forward roadway 83% of the time during baseline driving and 88% of the time while talking or listening on a mobile phone (Hickman & Hanowski, 2012). This might suggest a protective effect of talking or listening on a mobile phone while driving (Victor et al., 2014). However, as already noted, no single methodology paints the full picture of the effect of mobile phone use on crash risk (Caird et al., 2014). Increased forward gaze may for example indicate inattention blindness and 'tunnel vision', commonly reported findings during studies of participants conversing on mobile phones while performing a driving task (Strayer, Watson & Drews, 2011). Inattentional blindness refers to an inability to pay attention to all relevant stimuli in the environment that would usually be attended to when not conversing on a mobile phone. Tunnel vision meanwhile refers to the closing off of peripheral vision to focus on only the road ahead when conversing on a mobile phone while driving. Studies suggest that drivers not conversing on a phone are twice as likely to recall objects during a drive as drivers who are conversing on a phone (Strayer et al., 2011). Further studies reported by Strayer et al. (2011) suggest that when drivers are engaged in a phone conversation it is their encoding of peripheral information that is compromised rather than their recall, presumably due to the additional cognitive demands of the conversation at the time.

Data from 100-Car study suggest that while conversing on a mobile phone has a lower risk than other demanding phone related tasks (e.g. dialling a phone), because conversing lasts for longer and has greater exposure, at a population-risk level, it is just as risky as more momentary tasks such as dialling that require eyes-off-the-road (Klauer et al., 2006). The crash risk associated with the cognitive impairment from conversing on a mobile phone is therefore more complex and subtle than other momentary physical and visual distractions, which arguably lend themselves to event related data coding such as those employed in naturalistic studies. The role of cognitive impairment when conversing on a phone while driving may also help explain the lack of any obvious difference in the detrimental effects of hands-free and hand-held phone use on driving performance (e.g. Burns et al., 2002).

There is increasing evidence and acceptance that the use of technology must be considered as task specific rather than device specific. For example, the use of a mobile phone while driving can involve tasks such as locating the phone, answering a call, finding a contact, dialling a number, reading a text, writing a text, playing a game, accessing the internet, map reading and satellite navigation. Each of these sub-tasks of mobile phone use is likely to require varying forms of physical, auditory, visual and cognitive resources. In general, studies suggest that conversing on a mobile phone is not as risky as locating the phone, dialling the phone or texting (Klauer et al., 2014; Victor et al., 2014) and that one of the critical factors in this differentiation is the time the eyes are off the road (Simons-Morton et al., 2014; Victor et al, 2014). Long glances away from the forward roadway appear to be strongly related to the risk of being involved in a crash or near crash (Simons-Morton et al., 2014; Victor et al, 2014). Conversing on a mobile phone while driving has in some studies been shown to have an unintended benefit of reducing eyes-off-the-forward roadway compared with baseline or normal driving. This may help to explain the null or protective effects observed during naturalistic studies for some crash types (i.e. drivers' eyes are forward and less likely to miss a salient cue requiring evasive action) and may also explain why simulator studies show that drivers conversing on a mobile phone are less likely to remember signs and other information that is in the driver's periphery.

The differing effects found from studies using various methodologies can therefore be largely explained by behavioural adaptation and task-specific effects that require further elucidation (Kinnear & Helman, 2013; Klauer et al., 2014; Victor et al., 2014). The studies to date help to build an understanding of the impact that distraction and the use of technologies can have on driver performance and safety. They suggest that specific secondary tasks that are visually and manually demanding (e.g. texting) are more likely to increase crash risk than cognitive tasks, which the driver may be able to partially offset the increased demand while maintaining eyes on the road. Nevertheless, the cognitive impairment of engagement in a secondary non-driving related activity, such as speaking on a mobile phone, is likely to have greater levels of exposure and the safety risks may be more difficult to detect in 'crash or near crash' coded naturalistic studies.

For this understanding to be developed further, for example through the comparison of data and meta-analyses, a universal and consistent definition of distraction is necessary.

2.3.2. Defining distraction

'Distraction' within the context of driving is a surprisingly embedded term amongst researchers, policy makers and the public. However, inconsistencies in the definition of 'distraction' and 'inattention' have led to difficulties in developing a consistent evidence base from which to draw conclusions (Regan, Hallet & Gordon, 2011). There are two reasons for this. First, in the absence of a common definition, distraction-related crash data are inconsistently collected and reported (Beanland, Fitzharris, Young & Lenné, 2013). Second, studies measuring distraction are often incomparable as it is not clear whether researchers are in fact measuring the same thing (Lee, Young & Regan, 2008). To address these issues researchers have sought to reach agreement with regard to a standardised definition of distraction.

One approach to establishing an accepted definition of a concept is to reach agreement from eminent domain experts. In one example of this approach, Hedlund, Simpson and Mayhew (2005) report of an agreed definition of distraction by a group of domain experts at an International Conference on Distracted Driving in Canada in 2005:

> "a diversion of attention from driving, because the driver is temporarily focusing on an object, person, task or event not related to driving, which reduces the driver's awareness, decision making ability and/or performance, leading to an increased risk of corrective actions, near-crashes, or crashes" (p2).

Basacik and Stevens (2008) similarly conducted an expert workshop in 2007 with the key activity to agree a definition of driver distraction in order to measure driver distraction, relate it to road safety risk and give policy advice. Reporting of the structured discussion is detailed, and agreements reached on key discussion points can be seen, in Table 3.

The final agreed definition of driver distraction from Basacik and Stevens (2008) is as follows:

> "Diversion of attention away from activities required for safe driving due to some event, activity, object or person, within or outside the vehicle.
>
> Note 1: safe driving requires monitoring of the road and traffic environment (which includes pedestrians and other road users) and control of the vehicle.
>
> Note 2: safe driving also requires an appropriate degree of attention and vehicle control to maintain a reasonable safety margin allowing for unexpected events.
>
> Note 3: types of distraction may be visual, auditory, biomechanical or cognitive, or combinations thereof." (p44).

This definition is similar to that of Hedlund et al. (2005), although it was clearly felt necessary to provide additional detail regarding the working definition of 'safe driving' and 'distraction types'.

Table 3: Key discussion points and expert group agreement for defining distraction (Basacik & Stevens, 2008)

Discussion point	Expert group agreement
Distraction, fatigue, inattention & internal thoughts	• Distraction excludes driver fatigue and impairment. These are related but distinct concepts. • Distraction requires a definable trigger and excludes daydreaming and general internal thoughts.
Distraction from what?	• 'Activities required for safe driving' is taken as the task from which distraction occurs, with the implication that this requires lateral and longitudinal control of the vehicle in the road and traffic environment (which includes pedestrians and other road users) such that a suitable safety margin is maintained.
Distraction as a continuous variable	• Distraction is a continuous variable. Distraction becomes critical when there is a shortfall between the activities required for safe driving and the resources devoted to it by the driver.
Distraction and consequence	• Drivers can be too distracted and/or driving in an unsafe way even if there is no immediate adverse consequence of the behaviour, such as an actual crash. Safe driving requires more than avoiding crashes although measuring safe driving is challenging.
Distraction and chance	• The degree of driver distraction is time varying, as are the demands of safe vehicle control, and unsafe situations can develop rapidly and unexpectedly. All other things being equal, reducing distraction improves the chance of the driver dealing appropriately with an unsafe situation.
Distraction and driver initiation	• Distraction should be considered as arising from both driver initiated and non-driver-initiated sources.
Types of distraction	• Appreciating the different types of distraction may inform future studies but our current understanding and ability to measure their role is limited.

Using a similar methodology to that of Basacik and Stevens (2008), Foley, Young, Angell & Domeyer (2013) conducted a literature review to collate working definitions of distraction, followed by an expert survey and workshop. The aim was to agree on a definition of distraction to enhance the ability of researchers to code distraction-related crashes. Foley et al. agreed on an existing definition, that of Regan et al. (2011):

> "Driver distraction is the diversion of attention away from activities critical for safe driving toward a competing activity, which may result in insufficient or no attention to activities critical for safe driving." (p1776)

Again the workshop concluded that 'distraction' excludes human conditions or states such as fatigue that impair a driver's ability to drive safely.

An alternative way to define a concept is by systematically reviewing, comparing and analysing definitions cited in the literature to reveal common features of the construct being researched (Regan et al., 2011). Two further definitions of distraction have been proposed from this approach:

"Driver distraction is the diversion of attention away from activities critical for safe driving toward a competing activity" (Lee, Young & Regan, 2008, p34).

"Driver distraction:

- Delay by the driver in the recognition of information necessary to safely maintain the lateral and longitudinal control of the vehicle (the driving task) (Impact)
- Due to some event, activity, object or person, within or outside the vehicle (Agent)
- That compels or tends to induce the driver's shifting attention away from fundamental driving tasks (Mechanism)
- By compromising the driver's auditory, biomechanical, cognitive or visual faculties, or combinations thereof (Type)"

(Pettitt, Burnett & Stevens, 2005, p11).

Further definitions of driver distraction have been proposed resulting from the observation of contributing factors in road crashes. Treat (1980, p21) and Hoel, Jaffard and Van Elslande, (2010, p576) respectively define distraction as occurring:

"…whenever a driver is delayed in the recognition of information needed to safely accomplish the driving task, because some event, activity, object, or person within [or outside] his vehicle, compelled or tended to induce the driver's shifting of attention away from the driving task"

"…from interference between a driving task and an external stimulation without [a] (*sic*) link with driving (e.g., guide a vehicle and tune the radio). This secondary task can be gestural or visio-cognitive"

Despite being developed by different approaches, all of these definitions of distraction are only subtly different and have key similarities, suggesting a convergence of agreement for defining distraction. Regan et al. (2011) suggest that definitions of distraction to date tend to contain the following elements:

- A diversion away from driving, or safe driving
- Attention diverted toward a competing activity, inside or outside the vehicle, which may or may not be driving related
- The competing activity may or may not compel or induce the driver to divert their attention toward it
- There is an implicit, or explicit, assumption that safe driving is adversely effected.

While the definition of distraction has therefore developed towards a common meaning, the relationship between distraction and inattention also needs to be considered.

2.3.3. Driver inattention

Unlike driver distraction, defining driver inattention has not received the same level of scrutiny. Regan et al. (2011) note that, where driver inattention has been defined, definitions have not been analogous. A summary of some definitions of driver inattention can be seen in Table 4.

What is apparent from the definitions of driver inattention in Table 4 is that some could be confused with definitions of distraction, while others attempt to separate themselves from distraction by referring specifically to driver states, such as mind-wandering or drowsiness. It is therefore pertinent to clarify the relationship between driver distraction and driver inattention.

There are essentially two schools of thought with regard to the relationship between driver distraction and inattention. One asserts that driver distraction and driver inattention are separate concepts, while the other asserts that they are related concepts. Some argue, for example, that the difference between them is that driver distraction is external and requires a competing activity, whereas driver inattention is internal and relates to pre-occupation with an internalised thought (Caird & Dewar, 2007; Hoel et al., 2010; Lee et al., 2008). The difficulty with this description is that driver inattention is not necessarily always due to internal processes and in this context is possibly being utilised to describe undefined concepts such as mind-wandering. It appears more logical to consider, as Pettitt et al. (2005), Regan et al. (2011), Engström et al. (2013) and Regan and Strayer (2014) note, that inattention simply relates to not paying attention to activities deemed necessary for safe driving and that distraction may lead to driver inattention, but inattention is not necessarily the result of distraction. Essentially, the product of this conceptualisation of the relationship between them suggests that driver distraction is merely one sub-set of factors that can cause driver inattention. By considering this relationship it is possible to develop a greater understanding and better definitions of driver inattention and driver distraction.

Table 4: Summary of various definitions of driver inattention

Definition	Reference
"…whenever a driver is delayed in the recognition of information needed to safely accomplish the driving task, because of having chosen to direct his attention elsewhere for some non-compelling reason"	Treat (1980, p21)
"…diminished attention to activities critical for safe driving in the absence of a competing activity"	Lee et al. (2008, p32)
"…improper selection of information, either a lack of selection or the selection of irrelevant information"	Victor et al. (2008, p137)
"Any condition, state or event that causes the driver to pay less attention than required for the driving task"	Wallén Warner et al. (2008, p12)
"…when the driver's mind has wandered from the driving task for some non-compelling reason"	Craft & Preslopsky (2009, p3)
"…low vigilance due to loss of focus"	Talbot & Fagerlind (2009, p4)
"…any point in time that a driver engages in a secondary task, exhibits symptoms of moderate to severe drowsiness, or looks away from the forward roadway"	Klauer et al. (2006, p21)
"…insufficient, or no attention, to activities critical for safe driving."	Regan et al. (2011, p1775)

2.3.4. Taxonomies of driver inattention

A taxonomy is essentially a meaningful categorisation of a process that is based on some underlying theory or data. The purpose of a taxonomy can be to further define a process or to provide categorisation for further analysis (for example, the categorisation of crash data). Engström et al. (2013) note that a taxonomy of inattention specifically needs to be relatively stable but also flexible to evolve over time with advances in technology, measurement technology and understanding of driver behaviour.

In reviewing previous taxonomies of driver inattention, Regan et al. (2011) concluded that attempts to conceptualise driver inattention highlight the lack of agreement and definition about the concept and its relationship with driver distraction (e.g. Hoel et al., 2010; Treat, 1980; Wallén Warner et al., 2008). Regan et al. (2011) provided a comprehensive consideration of driver inattention and distraction. Building on previous taxonomies, and derived from consideration of crash data (rather than attentional theory) they describe a theoretical framework that aims to provide a structure from which research (e.g. crash data analysis) can be designed.

Regan et al. (2011) define driver inattention as "…insufficient, or no attention, to activities critical for safe driving" (p1775). According to their definition, driver inattention includes situations where the driver:

1. Does not pay attention to the activity (or activities) most critical for safe driving
2. Gives insufficient attention to the activity (or activities) most critical for safe driving
3. Gives full attention to an activity (or activities) that is not the activity most critical for safe driving.

Driver distraction within this framework is just one form of driver inattention; it is termed Driver Diverted Attention (see Figure 2). Driver Diverted Attention (DDA) is the '…diversion of attention away from activities critical for safe driving toward a competing activity, which may result in insufficient or no attention to activities critical for safe driving' (p1776). This definition is later updated to '…the diversion of attention away from activities critical for safe driving toward a competing activity, which may result in inattention' (Regan & Strayer, 2014, p7). This definition is similar to the definitions of distraction by Lee et al. (2008), Hedlund et al. (2005) and particularly that of Basacik and Stevens (2008). However, Regan et al. further define DDA into two sub-categories: DDA non-driving-related (DDA-NDR) and DDA driving-related (DDA-DR). The differentiation of these two sub-categories appears to be simply the type of distractor. Non-driving-related DDA includes the use of non-driving-critical technology such as mobile phones, but also includes mind-wandering and day-dreaming. Driving-related DDA on the other hand defines circumstances where a driver's attention is diverted towards a competing task related to the overall task of driving, but one that is not safety critical. Attending to satellite navigation to re-route while driving might be a common example of DDA-DR; altering the navigated route is purposeful for the driving task but it is a non-safety-critical task and could divert attention from safety-critical stimuli in the driver's environment.

Figure 2 presents definitions of each of the components of Regan et al.'s taxonomy and provides examples based on information provided in Regan et al. (2011) and Regan and Strayer (2014).

With regard to the focus of the current project and the potential risk of modern and future technologies to impact attention the following components of inattention are likely to be of most interest:

- Driver Diverted Attention (DDA) – Both DDA-NDR and DDA-DR will be of most interest as drivers engage with new in-vehicle and mobile technologies, some of which will be driving related but non-safety-critical, and some of which will be comfort devices never critical for safe driving, or for driving at all.
- Driver Misprioritised Attention (DMPA) – New in-vehicle driver assistance technology may blur the line between DDA and DMPA. It may be necessary to additionally define this variable to include an over-reliance on driver assistance aids. For example, a driver who relies excessively on the use of an infrared camera at night rather than looking at the road scene may be considered to have misprioritised their attention rather than have diverted their attention to a non-safety-critical driving related task.
- Driver Neglected Attention (DNA) – Were new safety assistance technology to lead to drivers neglecting to pay attention to safety-critical stimuli in their environment due to an expectation that the system will provide a warning, then a rise in this type of inattention would be of concern. For example, might lane change assist

technology lead drivers to neglect to check their mirrors or look over their shoulder?

- Driver Cursory Attention (DCA) – Might new driver assist technologies lead drivers to pay cursory attention in situations where formerly they would have given their full attention? Using the same example as for DNA, lane assist technology may not lead to drivers' complete neglect of checking their mirrors or looking over their shoulder, but these basic safety checks might become cursory rather than fulsome.

The only component of Regan et al.'s taxonomy of inattention that new technologies are unlikely to impact is therefore Driver Restricted Attention (DRA), which relates to inattention resulting from physiological means (e.g. microsleeps, sneezing, blinking, etc.).

Another taxonomy of driver inattention is proposed by Engström et al. (2013) via the United States and European Union Bilateral Intelligent transportation Systems Technical Task Force (US-EU Bilateral ITS TF). The taxonomy (see Figure 3) categories are slightly broader than those of Regan et al. (2011) but share similarities with regard to the breakdown of inattention and distraction, as described in Regan and Strayer (2014).

This taxonomy, published after Regan et al. (2011), notes that all previous taxonomies are developed from the bottom-up; that is, they are developed from after-the-event crash data. Developing a taxonomy from the bottom-up leaves it open to hindsight bias (Rasmussen, 1990). Hindsight bias is where the attribution of attentional failure is assumed based on post-event knowledge, and may not reflect the actual attentional needs or failures at the time of the crash. Engström et al. (2013) instead developed a taxonomy based on attentional theory and key principles derived from existing scientific theory, driver behaviour models and related research.

Engström et al. (2013) define twelve key principles which underpin the taxonomy, summarised in Table 5. Several of these principles have important implications for the current project and the consideration of technology on driver attention. For example, it is possible that the results of naturalistic studies, that on the face of it oppose laboratory studies (see "The story so far" section at the beginning of Task 1.1), can be explained through consideration of attention as an adaptive behaviour. Engström et al. (2013) refer to attention deployment and selection as being necessary for the adaptation of safety margins. Recent models of driver behaviour (e.g. Fuller, 2011; Summala, 2005; 2007) refer to 'safety margins' as the driver's reference between the demands of the task and the driver's capability to complete the task and maintain safe progress. The concept of the 'safety margin' is referred to in various guises within driver behaviour literature such as 'task difficulty' (Fuller, 2011), 'comfort zone' (Summala, 2005, 2007) and 'driver workload' (de Waard, 2002).

These modern theories of driver behaviour essentially propose that drivers like to keep within a 'safety margin' that feels comfortable and therefore drivers manipulate demand (primarily through speed, but also via taking on or dumping other tasks such as speaking on the phone) depending on the state of many other factors in the environment (e.g. other road users, lane width, road geometry, lighting, etc.). Fuller (2011) terms this process of manipulation by the driver the 'theory of Risk Allostasis'.

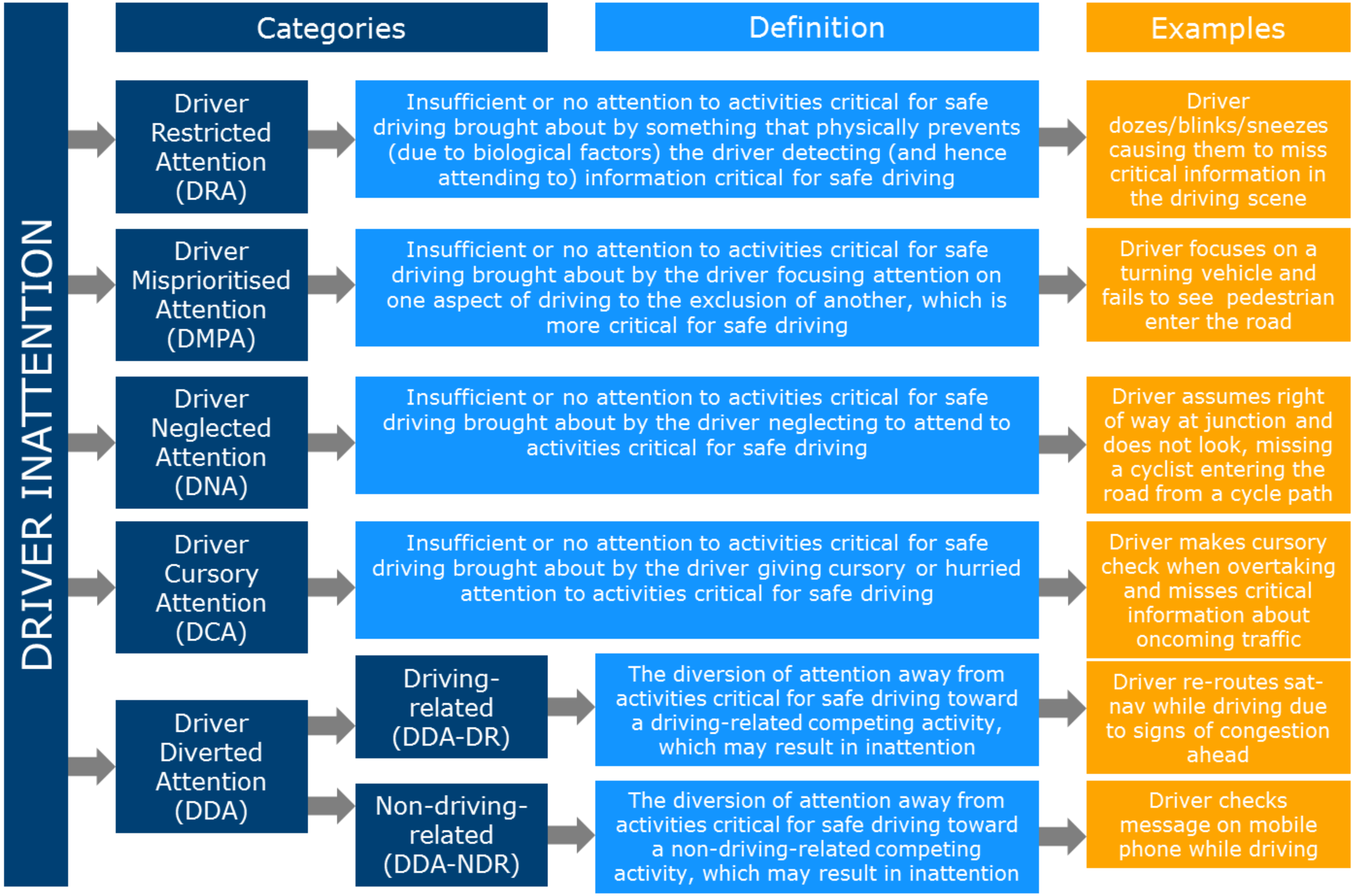


Figure 2: Diagram summarising Regan et al.'s (2011) taxonomy of driver inattention with definitions and examples (based on Regan et al. (2011) and Regan and Strayer (2014))

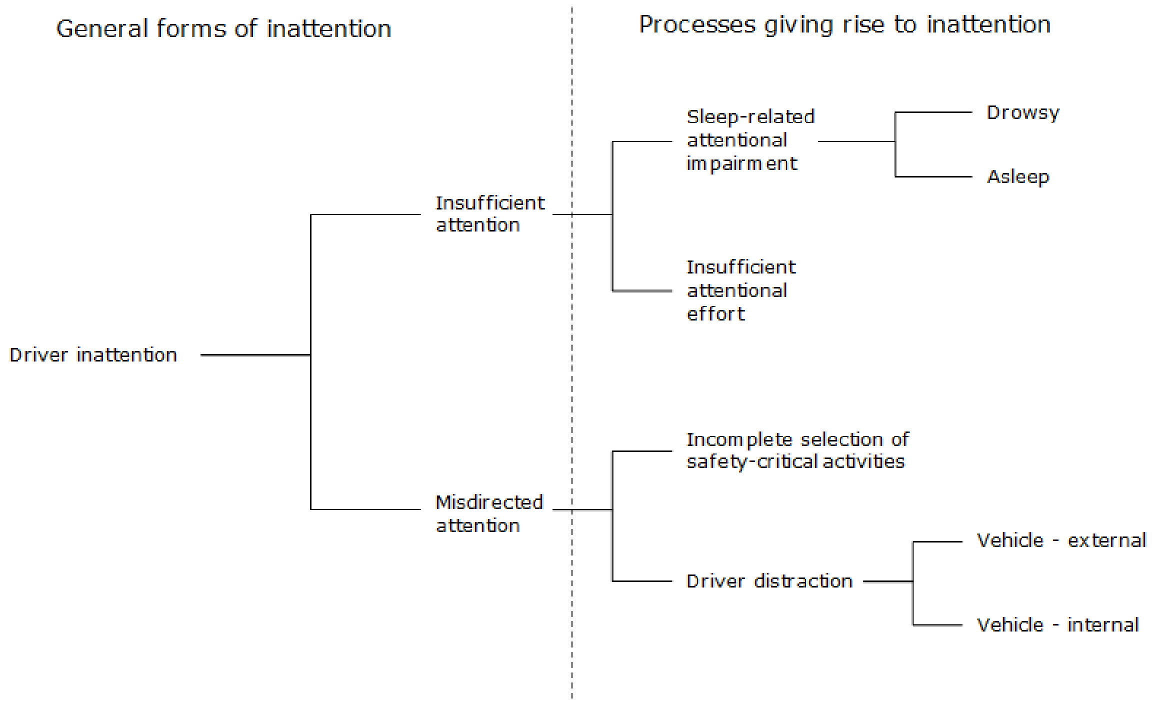


Figure 3: Graphical representation of the Engström et al. (2013) driver inattention taxonomy

Table 5: Key principles underpinning Engström et al.'s (2013) taxonomy of driver inattention

	Key Principle	Summary
1	Attention as adaptive behaviour	Attention must be managed by adapting behaviour in order to maintain an adequate safety margin (e.g. an adjustment in vehicle speed). Attention allocation in driving is an integral part of adaptive driving behaviour (Engström, Markkula & Victor, 2012).
2	Driver attention as the allocation of resources to activities	Attention requires applying resources (sensory, actuator, perceptual, motor or cognitive) to the activity. Momentary attention is therefore the current distribution of attention to the driving task or competing activities (e.g. a phone call).
3	Activities as more or less relevant to driving and more or less critical for safe driving	Activities when driving can be placed on a continuum from essential driving-related to entirely non-driving related. At one end are activities necessary for safe driving (e.g. gap maintenance) with non-driving related activities (e.g. phone call) at the other.
4	Driver attention as situated in an ecological context	Driving is a dynamic task where the environment is constantly changing and altering the amount of attentional resource required by the driver.
5	Activation and selectivity as a key dimension of attention	Activation refers to the degree to which resources are allocated to activities, which is partly determined by the demands of the activities. Selectivity refers to how the resources are distributed between the activities.

	Key Principle	Summary
6	Factors that drive activation	Factors that influence activation are determined by endogenous factors (alertness and attentional effort) and exogenous factors (nature of, and time spent on, the task). Closely linked with arousal, these factors relate to self-regulation within the task of factors such as fatigue and effort.
7	Factors that drive selection	Factors that influence selection are similarly determined by endogenous factors (goals and expectations) and exogenous factors (intensity, size, contrast, conspicuity of stimuli). Non-driving related influences, such as the emotional and social value of communicating (e.g. text message), may influence the selection of attention also.
8	Automatic versus controlled performance	Controlled and automatic performance are traditionally viewed as being distinguished by effort and consciousness (controlled being more effortful and under conscious control). This distinction is problematic in driving though as both forms are necessary (Trick, Enns, Mills & Vavrik, 2004).
9	Attention as an acquired skill	Differences between novice and experienced drivers' allocation of attention suggest that appropriate attention allocation is a skill acquired through repeated practice and exposure.
10	Interference between activities	Interference between two concurrent activities occurs when the demand for limited attentional resources overlaps and conflicts.
11	Functional limitations	Humans are functionally and cognitively limited. Drivers can find themselves compensating for these limitations in their driving behaviour (e.g. reducing speed to maintain safety margins).
12	Stimulus quality	Attentional mismatch might occur where stimulus quality is poor and therefore occluded from the driver. This might be due to the driver (e.g. blinking, rubbing eyes), physical factors (e.g. A-pillar interference), or environmental factors (e.g. insufficient lighting in the dark).

The effect of changes in driver behaviour as a result of increased or decreased workload when driving has been demonstrated in several studies. For example, it has been established that drivers often respond to increased mental workload by reducing speed when engaged in tasks such as making a phone call (Haigney et al., 2000; Burns et al., 2002) or reading and writing text messages (Reed & Robbins, 2008). Large percentages of drivers also report driving more slowly when driving in fog (98%), heavy rain (96%) and when on unfamiliar roads (88%) (Campbell & Stradling, 2003). Conversely, when workload drops, for example when roads are empty at night, mean speeds increase (Broughton, 2005). This simple effect has been noted in the behavioural adaptation literature with the installation of road lighting resulting in increased speeds and reduced concentration (Assum, Bjornskau, Fosser & Sagberg, 1999). These studies suggest that the amount of processing demand and effort required can inform a driver of some of the demand characteristics of the driving task and that this can result in a change in behaviour and presumably allocation and selectivity of attention. In addition, studies have used both conscious appraisal and physiological measures (e.g. heart rate) to detect workload (Brookhuis & de Waard, 1993), which suggests that physiological changes in the body can be used as indicators of mental workload. Mental workload is not a system of processing that necessarily relies on conscious cognition alone, if it is accepted that people can be influenced by processing and knowledge outside of their conscious awareness.

This understanding of drivers' adaptive behaviour and allocation and selectivity of attention suggests that drivers will be unwilling to engage in interfering secondary tasks when driving is demanding or uncertain. It also highlights a particular flaw in experimental studies of the dual task paradigm where participants are instructed to engage in secondary tasks that they would not normally choose to undertake during real-world driving. Of course, drivers' abilities to adapt do not necessarily result in a necessary safety margin being maintained where drivers have erroneous expectations of the driving environment, overestimate their abilities, or have strong motivations to engage with another task irrespective of demand (for example, the social and emotional motivation to engage with others via a mobile- or smart-phone (e.g. Vuilleumier, 2005)).

Engström et al. (2013) therefore state that "…inattention occurs when the driver's allocation of resources to activities does not match the demands of the activities required for the control of safety margins" (p25). This perspective of attention is all encompassing, representing attentional failures as part of a driver-vehicle-environment system rather than inattention resulting from driver failure alone. This perspective is different from the crash analysis perspective whereby the reconstruction proposes where the driver should have been attending, and instead simply states that resource allocation did not match the demand of the activities critical for safe driving at that particular moment.

2.3.5. Activities critical for safe driving

Another important consideration for the current research relates to the fact that almost all definitions and taxonomies of driver inattention and distraction rely on a term like 'activities critical for safe driving'. Defining the activities and stimuli that a driver should attend to at any one moment is clearly difficult and no one specified definition can be applicable to all dynamic driving scenarios. It is only with hindsight that researchers are able to identify what activities were critical in a particular scenario, and therefore define what the driver should have been attending to (Hancock, Mouloua & Senders, 2008). Regan et al. (2011) suggest that the most productive way to understand and define the 'activities critical for safe driving' is to focus on developing a consistent taxonomy of activities from crash and observational studies. In the meantime, Engström et al. (2013) simply defines such activities as "…those activities required for the control of safety margins" (p17).

2.3.6. Validation

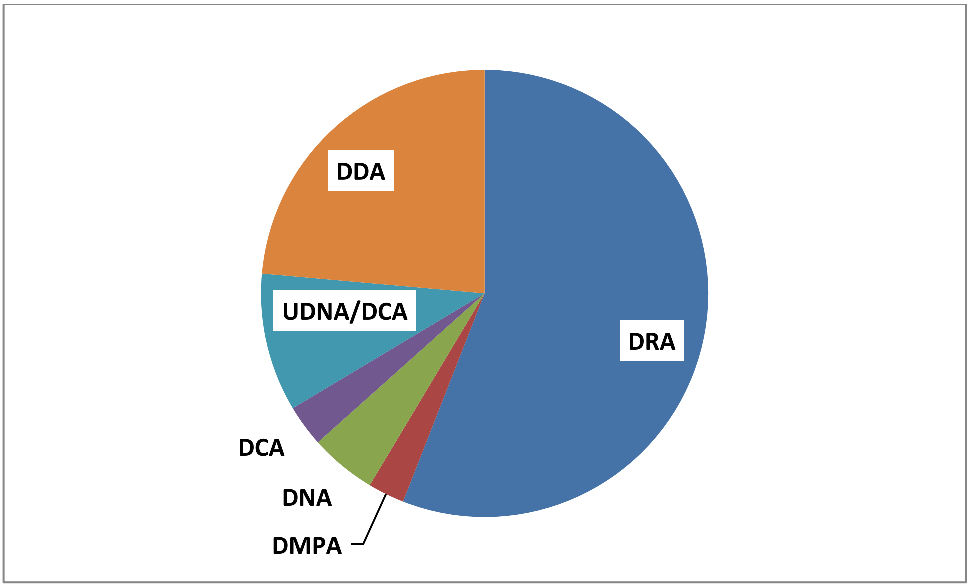
In furthering the definition of driver inattention (in which distraction is just one of several factors that may give rise to inattention) Regan et al.'s taxonomy provides a foundation on which future Tasks in this project can be based; the application of attentional theory further assists the understanding of attentional adaptation, allocation and selection (Engström et al., 2013). In a follow-up publication, Regan and Strayer (2014) note that Engström et al.'s (2013) taxonomy is very similar and can in the most part be mapped onto Regan et al.'s (2011) taxonomy. The complementary nature of taxonomies developed from the top-down and bottom-up provides confidence in the devised concepts.

In addition to Regan and Strayer's (2014) allocation of attentional theory to support the structure and definition of the Regan et al. (2011) taxonomy, it is also necessary for validation that the definitions afforded by either taxonomy can be distinguished both theoretically and practically, via the application of crash data.

The literature found for this review suggests that only one study has utilised either taxonomy to code crash data. Beanland et al. (2013) used data from the Australian National Crash In-Depth Study (ANCIS) to code 856 crashes from 2000-2001 in which at least one party was admitted to hospital with a crash-related injury. In coding the crash descriptions Beanland et al. further categorised Driver Diverted Attention (driver distraction):

- Relationship with the driving task (driving or non-driving related, as per the original taxonomy)
- Origin of distractor (driver's mind, in-vehicle, external to vehicle)
- Sensory modality of the distractor (visual, auditory, physical, cognitive)
- Diversion of attention (voluntary or involuntary).

Figure 4 summarises the proportion of crashes in each category of Regan et al.'s taxonomy.



Key: DRA-Driver Restricted Attention; DMPA-Driver Miprioritised Attention; DNA-Driver Neglected Attention; DCA-Driver Cursory Attention; UDNA/DNA-Undifferentiated DNA/DCA; DDA-Driver Diverted Attention

Figure 4: Results of Beanland et al.'s (2013) classification of crash data using Regan et al.'s (2011) taxonomy of driver inattention

Beanland et al. (2013) note some difficulties in differentiating between components of inattention as defined by Regan et al. (2011). For example, they recommend that for coding crash data, a new category be defined where it is not possible to determine if the driver failed to look properly (DNA) or they looked but failed to see (DCA). In addition, it is noted that there was often some debate as to whether a situation was misprioritised attention or driving-related distraction. Beanland et al. differentiated that it was dependent on the whether the secondary task was safety-relevant or not. This is clearly a difficult judgement to make, and it would be necessary to make it on a case-by-case basis.

Even with current in-depth crash data, the detail necessary to correctly allocate crash pre-cursors to types of inattention is difficult. Regan and Strayer (2014) suggest that the taxonomy requires further validation from the application of detailed naturalistic driving data. Meanwhile, the introduction of new vehicle technologies is likely to require further definition and clarification of the taxonomy in future.

2.3.7. Specific road user groups

In sections 2.3.7.1 to 2.3.7.6, evidence from the review relating to specific road user groups is presented. Specific challenges relating to each group (in exposure or susceptibility to distraction effects) are noted.

2.3.7.1. Professional and occupational drivers

Professional and occupational drivers as defined here incorporate all those who drive as part of their work or for work, including car, light goods vehicle, Heavy Goods Vehicle (HGV) and bus drivers. Where research specifically relates to a specific type of professional or occupational driver this will be made clear. This group as a whole is of specific interest as in-car distractions (specifically through technologies such as mobile phones) have been shown to be a specific risk in this type of driving (see Salminen & Lähdeniemi, 2007 and Broughton, Baughan, Pearce, Smith & Buckle, 2003, both cited in Grayson & Helman, 2011).

There has been little research of distracted driving in HGV and bus drivers, and in particular the use of technologies (Hickman & Hanowski, 2012). One prominent study in this area is the Large Truck Crash Causation Study (LTCCS; FMCSA, 2005) that was based on a nationally representative sample of almost 1,000 injury and fatal crashes that occurred in the USA between April 2001 and December 2003. This study found that nine percent of injury and fatal truck crashes were attributable to driver inattention, eight percent to external distraction, and two percent to internal distraction. It is important to note that these proportions relate to inattention or distraction being the causal factor for the crash (i.e. without this factor, the crash could have been avoided), rather than merely a contributory factor.

Olson et al. (2009) collected naturalistic data from 203 HGV drivers from seven different fleets in the USA. 4,452 'safety-critical' events were recorded, comprising 21 crashes, 197 near crashes, 3,019 crash relevant conflicts, and 1,215 unintentional lane deviations. Olson et al. reported that drivers were performing tasks unrelated to driving during 56.5% of the safety-critical events. In addition, drivers who texted while driving were 23 times more likely to be involved in a safety-critical event than drivers who did not. Further, drivers who talked on a mobile phone (hands-free or handheld) while driving were no more likely to be involved in a safety critical event than those who did not. It should be noted however that 'safety critical' as defined in this study is somewhat subjective and the outcomes may not reflect greater crash risk *per se*. For example, an unintentional lane deviation on an open road with clear visibility and no traffic, while undesirable, may not result a crash. With only 21 crashes recorded, the role of inattention on driver crash risk cannot be reliably determined from this study.

In attempting to address this common limitation of naturalistic studies (a reliance on 'safety critical' events rather than crashes), Hickman and Hanowski (2012) analysed an extensive in-cab data obtained from 183 HGV and bus fleets comprising 13,306 vehicles and 1,000 crashes. Nevertheless, the data were obtained from the monitoring system provider and may contain bias given that fleets using a monitoring system may be from more safety conscious organisations. In addition, the technology used had previously been evaluated and shown to reduce safety critical events per 10,000 miles by 70% for short- and long-haul drivers (Hickman & Hanowski, 2011). It is for these reasons that Hickman and Hanowski (2012) recommend caution when interpreting their results that driver distractions were lower than those reported in previous studies (e.g. FMCSA, 2005; Olson et al., 2009). Indeed the rates were so low that they could not calculate odds ratios for distraction and crashes.

It was however concluded that there was a strong relationship between texting/emailing/internet use and involvement in a safety-critical event. As with other studies (e.g. Klauer et al., 2006) Hickman and Hanowski (2012) found that talking or listening on a mobile phone while driving did not increase the chances of being involved in a safety-critical event. As noted in 'the story to date' at the beginning of Task 1.1, there is evidence that drivers self-regulate the demand of the driving task when engaging in a phone conversation by manipulating their speed, following-distance and focus on the forward roadway. In examining this issue with commercial drivers Fitch, Grove, Hanowski and Perez (2014) found very few differences in driving behaviour when drivers were engaged in a phone conversation. The main difference proposed to offset the increased demand of the phone conversation task (and risk) for commercial drivers was increased visual attention to the forward roadway.

Griffin et al. (2014) looked at the prevalence of distraction for transit bus drivers in an observational study. They found that bus drivers were distracted on 39% of their stop-to-stop journeys with passengers being the primary distractors. Mobile phone use and engaging with the ticket machine each occurred on 4% of the journeys.

2.3.7.2. Young drivers

Young drivers have received specific attention for being both the most likely group of drivers to use technology and electronic devices and for their association with being inexperienced and at greater crash risk. The increasing utilisation of portable electronic devices (particularly smartphones) by young people in particular is widely reported (Green, 2003). Meanwhile it is well established that newly licensed inexperienced drivers (who are usually also young) are at greater crash risk due to a lack of mature visual search patterns, poor calibration of experienced risk with actual risk, over-confidence, and an inability to anticipate hazards effectively (Deery, 1999; Fuller, McHugh & Pender, 2008; Kinnear, Kelly, Stradling & Thomson, 2012).

Secondary tasks that take drivers' eyes off the road, reduce the extent of their visual scanning, or increase cognitive load are of particular concern for young drivers who may not appreciably detect the increased risk associated with these additional tasks while driving. Simons-Morton et al. (2014) report a naturalistic driving study with 42 newly licensed drivers whose cars were instrumented to collect data for 18 months of their early driving career. The study was particularly interested in the relationship between 'eyes off the road' time and crash or near crash events. The six second period prior to each crash or near crash (CNC) event was coded for the longest eye glance off the roadway (LGOR) and the total duration of eye glace off the roadway (TEOR). Results suggest that when the LGOR was greater than 2 seconds due to engagement with a mobile communication device there was a greater risk of a CNC event. For each additional second the risk of a CNC increased. However, while the TEOR was associated with CNC risk in general, this was not true for mobile communication devices. This might suggest that multiple short glances (e.g. <1s) are more beneficial than longer single glances. In an further exploratory naturalistic study Foss and Goodwin (2014) found that while long glances away from the road for >2 seconds were relatively rare, they were strongly associated with the use of electronic devices. This study also notes that reliance on telematics-recorded events alone as an indication of distraction is not appropriate for studying young drivers as the vast majority of harsh braking events coded were the result of driver misjudgement unrelated to any distracting activity.

Simulator and test-track studies indicate that young novice drivers are not as adept at managing secondary tasks, such as using a mobile phone while driving, as older more experienced drivers (Hancock, Lesch & Simmons, 2003; Horrey et al., 2009; Lee et al., 2008; Reed & Robbins, 2008). In these studies, young drivers using a mobile communications device while driving were more likely to deviate from their lane and enter an intersection on a red or amber light than older, more experienced drivers. It is also reported that young drivers are more likely than older drivers to look away from the road for longer periods of time during in-vehicle secondary tasks (Chan et al., 2008).

Using the same naturalistic data as Simons-Morton et al. (2014) and data from the 100-car-study, Klauer et al. (2014) examined the effects of specific types of distraction on crash risk. In this study sub-categories of mobile phone use were defined (reaching for a mobile phone, dialling a mobile phone, talking on a mobile phone and sending or receiving a text message or using the internet). Using a similar approach to analysis to that of Simons-Morton et al., the data indicate that young novice drivers' risk of a crash or near crash increases when reaching for, dialling or texting on a mobile phone while driving. Among experienced drivers, only dialling a mobile phone was associated with increased crash or near-crash risk. Klauer et al. conclude that all of the tasks involve the young driver looking away from the road. Talking on a mobile phone was not related to crash or near crash risk. This suggests that crash risk for young drivers may be mostly associated with looking away from the road, although the deterioration of driving performance due to talking on a mobile phone should not be dismissed entirely (Klauer et al., 2014). Talking on a mobile phone can be rarely achieved without reaching for it and dialling or answering a call. As in-vehicle technology develops additional research will be necessary at the 'sub-task' level to understand what activities pose the greatest risk to road user safety.

2.3.7.3. Older drivers

Studies of older drivers indicate age related decline in visual perception and cognitive executive functions that affect their driving (Aksan et al., 2013). However, older drivers appear to compensate for such limitations by choosing when and where they drive and also how they drive, such as slowing down to increase their safety margin (Charlton et al., 2006). A TRL study for the Institute of Advanced Motorists (IAM) in the UK found that while older drivers took around a second longer to respond to a pedestrian walking out from behind a parked car than did younger drivers (in a simulated scenario), because of their slower initial speed they stopped further from the pedestrian than younger drivers (Reed, Kinnear & Weaver, 2012). Most older drivers also have a wealth of driving experience and do not appear to have greater crash risk when driving distances are controlled for (Hakamies-Blomqvist, Raitanen & O'Neill, 2002).

There is a large body of research on the effect of age on dual task performance, which is beyond the scope of this review. A meta-analysis by Riby, Perfect and Stollery (2004) concluded that there was a strong overall effect of age on dual task performance where increasing age was associated with poorer performance. However not all studies find this (Fofanova & Vollrath, 2011). Subsequent analysis identified that task domain is a critical determinant of age related effects; substantial controlled processing (e.g. episodic memory) and motor tasks show greatest age-related effects (Riby et al., 2004; Fofanova & Vollrath, 2011).

Studies conducted prior to the search criteria used here appear to indicate that the effect of mobile phone use while driving is exaggerated for older drivers when compared with other age groups (e.g. Cooper et al. 2003; Hancock et al., 2003; Reed & Green, 1999). Studies have also reported that older drivers demonstrate greater difficulty when following route guidance technologies (Dingus et al., 1997). Fofanova and Vollrath (2011) tested the effect of secondary task distraction on older drivers in a simulated driving environment. The results showed that older drivers' (60-73 years) driving performance (as measured by the mean deviation from an ideal path) was worse than that of mid-age (31-44 years) drivers. Older drivers' lane keeping was also more affected than the mid-age drivers although the secondary task distraction did not impact their reaction times any more than it affected mid-age drivers' reaction times.

2.3.7.4. Motorcyclists

Only one study was returned from the literature search relating to motorcycling. The study was an in-depth investigation of 245 Powered Two Wheeler (PTW)-car accidents in Europe where the causation factors were solely human error (Penumaka, Savino, Baldanzini & Pierini, 2014). The study identified that car drivers predominantly made perception, comprehension and execution failures, while motorcyclists made perception and execution failures resulting in accidents. Unfortunately the study does little to inform of the potential role of distraction in such accidents.

2.3.7.5. Bicyclists

While distraction when driving endangers other road users, distraction when cycling largely endangers the bicyclist. This is a recent topic of study with very few published experimental studies. A recent review found only two previous experimental studies of distraction when cycling and four surveys highlighting the use of portable electronic devices when cycling as a growing trend (Mwakalonge, White & Siuhi, 2014). A further experimental study since this review has also been published (de Waard et al., 2014).

All of the published experimental studies to date have been conducted in the Netherlands (de Waard, Schepers, Ormel & Brookhuis, 2010; de Waard, Edlinger & Brookhuis, 2011; de Waard et al., 2014). These studies indicate that the effects of mobile phone use on cycling behaviour are similar to the effects of mobile phone use on driving behaviour. When talking or texting on a mobile phone while cycling bicyclists travel at slower speeds, miss more information from the periphery and swerve more within the bike path (de Waard et al., 2010; 2011; 2014). Bicyclists also report experiencing greater workload and risk when engaging with a mobile- or smart-phone when cycling.

De Waard et al. (2011) compared the effects of hands-free and hand-held phones and found only limited advantages to hands-free use when cycling. The main advantage was the ability to stop quicker by virtue of having both hands free with which to apply the brakes; however, the distracting effects were similar in both conditions. De Waard et al. (2014) meanwhile established that the use of touchscreen phones for texting has some additional effects on cycling behaviour when compared with traditional mobile phones with tactile solid keys. When using a touchscreen smartphone, bicyclists were found to keep further from the kerb and detect fewer objects in their periphery than when using a traditional mobile phone.

The results of these early cycling distraction studies somewhat reflect the early experimental studies of the effects of mobile phones and driving. The attentional detriment brought about by secondary task use of portable electronic devices is clear, although how this translates into increased crash and casualty risk is unknown since there are no naturalistic studies or appropriate studies of injury risk to draw on.

2.3.7.6. Pedestrians

As with bicyclists, there is only a small body of research detailing the distracting effects of portable electronic devices on pedestrian behaviour. Nevertheless, secondary task use of devices such as mobile phones appears to have similar effects for pedestrians as it does for drivers and bicyclists, particularly with regard to reduced peripheral attention (White et al., 2014).

Experimental studies of pedestrian behaviour tend to focus on crossing behaviour, presumably because it offers the most critical time when pedestrians and motor vehicles interact. Such studies compare pedestrians with no distractors with those texting or engaging with a mobile phone call or listening to music (e.g. Hyman et al., 2010; Nasar, Hecht & Wener, 2008; Neider et al., 2010; Schwebel et al., 2012).

Taken together, these studies suggest that successful crossing behaviour is compromised when engaged with another activity, with texting on a mobile phone in particular increasing the likelihood of being hit by a vehicle in a simulated environment (Schwebel et al., 2012). Studies with children (Stavrinos et al., 2009), adults (Neider et al., 2010; Stavrinos et al., 2011), and older adults (Neider et al., 2010) also found increased pedestrian risk when talking on the phone compared with undistracted controls, although this was not found by Schwebel et al. (2012).

Listening to music is also found to impact negatively on successful pedestrian crossing behaviour (Schwebel et al., 2012). While music is not generally thought to be as cognitively resource intensive as engaging in a phone conversation, it is postulated that it can disrupt auditory cues that may be important for judgement in a pedestrian environment.

2.4. Statistical and accident data on road user distraction

2.4.1. Recording distraction related accidents in Europe

Police accident forms or recorded data from 16 countries were obtained (Belgium, Czech Republic, Estonia, Finland, Germany, Greece, Hungary, Ireland, Latvia, Malta, The Netherlands, Poland, Portugal, Romania, Sweden and Great Britain (GB)).

Of these, only three countries (Portugal, Ireland and GB) record any information on distraction in their national accident reporting form. Portugal only records that distraction was a factor without specifying in detail what type. Ireland and GB provide options of mobile phone use, distracted by action inside the vehicle and distracted by action outside the vehicle as contributory factors.

The road safety experts in Belgium, Czech Republic, Ireland and Sweden also provided national reports on distraction, although these tended to focus on the frequency of distraction in traffic rather than distraction as a contributory factor in road accidents.

2.4.2. Estimates of driver distraction

The review of data-led reports and presentations on the impact of driver distraction on accidents in Europe suggests that it is very difficult to accurately define distraction, and equally difficult to estimate occurrences. There are estimates in various reports of how much distraction is an influencing factor in road accidents within Europe. Reports such as DaCoTA (2012) and SWOV (2013) report that in approximately 5% to 25% of car crashes driver distraction ‘plays a role’ with one study estimating that 70% of truck driver accidents had distraction-related contributory factors (Hurts et al., 2011).

DEKRA (2012) reports on a safety study in 2001 carried out via a representative survey of car drivers in Germany, Austria and Switzerland by the Allianz Centre for Technology. The study suggested that 10% of car accidents are caused by distractions while driving. More recently, police assessments of road accident statistics in Austria suggest that approximately 35% of all injury road accidents were inattention- or distraction-related, with the corresponding figure for fatal road accidents being 12% (Austrian Road Safety Fund, 2012).

The results from a 2010 survey in Italy reports a much larger proportion of road accidents where distraction was a causal factor. Fifty-six percent of respondents reported that they had had an accident (although it was not clear what period this covered) with 44% of the 56% of respondents stating the main cause as being distraction (Guidoni, 2014).

Spain also appears to have a large problem with distraction, with it appearing as a concurrent factor in 38% of casualty accidents on average in 2013, with the proportions being 44% outside urban areas and 33% inside urban areas. These results were acquired from road safety statistics by Spain's National Institute of Statistics (Dirección General de Tráfico (DGT), 2013).

Distraction is not reported to be as large a contributory factor to road accidents in Greece, with 11.5% of road accidents estimated to be distraction-related in 2010 based on data collected by the Greek police force. For fatal accidents, it is estimated that 4.4% are distraction-related (Chrysostomou, 2011).

In Britain, the DfT (2014) reports that in 2013 there were 2,995 cases where distraction in the vehicle listed as a contributory factor, making up 3% of all reported injury road accidents, and 1,627 where distraction outside the vehicle was a contributory factor, making up 1% of all such accidents. Of these, 84 and 27 were fatal accidents, making up 6% and 2% of all reported fatal road accidents respectively.

The SafetyNet Accident Causation Database comprises data collected by six EU member states: Italy, Germany, Sweden, Norway, UK and The Netherlands. Investigations were carried out at institutions in these countries and it was found that of the 1,005 crashes recorded, 320 (32%) involved at least one driver, rider or pedestrian which had been assigned the labels 'Distraction' and/or 'Inattention' (Talbot et al., 2013).

Thomas et al. (2013) presents slightly different results from an alternative report based on SafetyNet data; data included from France were included rather than The Netherlands. Of the 997 accidents recorded, 182 (18%) had distraction as a contributory factor and 123 (12%) had inattention as a contributory factor, making up approximately 31% of all the accidents. Table 6 shows the distribution of these accidents by vehicle and type of distraction, along with the percentage of the whole dataset each distraction type represents. Note that the table includes accidents with distraction as a contributory factor only and that the percentages do not add to total due to rounding.

Table 6: Number of accidents with different distractions by vehicle as a contributory factor in SafetyNet in-depth database (Thomas et al., 2013)

	Car driver	Motorcyclist	Pedestrian	Bicyclist	Total	Percentage of all accidents
Passenger	36	0	0	0	36	4%
External competing activity	57	5	11	5	78	8%
Internal competing activity	49	0	6	1	56	6%
Other	7	2	2	1	12	1%
Totals	**149**	**7**	**19**	**7**	**182**	**18%**

Table 7 collates the figures from the various reports for a variety of countries as discussed above.

Table 7: Reported figures of distraction in road traffic accidents for various countries

Country/Countries	Distraction related accidents %	Year(s)
Austria	12%	2012
Austria, Germany, Switzerland	10%	2001
France, Germany, Italy, Norway, Sweden, UK	18% (31% including inattention)	2013
Germany, Italy, Netherlands, Norway, Sweden, UK	32% (some inattention also)	2013
Greece	11.5%	2010
Italy	54%	2010
Spain	38%	2013

2.4.3. Distraction and technology in road accidents

Overall there was only one report that included any figures on road accident statistics where distraction by an electronic device was a contributory factor. It could be speculated that difficulties in retrospectively identifying cases of distraction due to interaction with technologies has led to poor (or no) recording of such factors. There is also the possibility that not many studies have been completed due to the recent advent of devices such as smart phones and tablets to mass market consumers.

The one report that was identified showed that mobile phone use in GB was a contributing factor in 422 road accidents in 2013 (less than 1% of all reported injury road accidents; DfT, 2014). The proportion of reported fatal road accidents with mobile phone use as a contributing factor was 1.5%, there being 22 cases of 1,486 recorded. As noted above, it is expected that these figures are an underestimate due to the difficulty of recording such data retrospectively.

2.4.4. European and in-depth databases

The following data sets have been investigated and where possible searched for any distraction related data:

- Road Accident In-depth Studies (RAIDS), and within it the On-the-Spot database (OTS), the British in-depth accident study
- Community Road Accident Database (CARE), the European combined accident database
- German In-Depth Accident Study (GIDAS)
- SafetyNet, a European in-depth study completed as part of an EU project.

The backgrounds for each are given below, along with information on any data acquired.

2.4.4.1. On-the-Spot (OTS) crash studies

OTS was an accident data collection study where the objective was to collect high-quality crash data to improve understanding of human, vehicle and highway factors in accident causation and injuries. During the course of the project, a subset of road traffic accidents taking place between 2000 and 2010 in two distinct geographical regions in GB was investigated. Data were collected by expert investigators who typically attended the scene of an accident within 15 minutes of it occurring in order to collect data that would otherwise have been lost if investigated later (such as weather conditions, tyre marks on the road, and final positions of vehicles). The crash scene investigation took place while emergency services were present and focussed on vehicle, road user and highway issues.

Vehicle damage was recorded by photographs and written observations, from which investigators determined the seriousness of the collision and what vehicular damage may have caused any injuries to a casualty. Injury data were collected post-accident in liaison with emergency services, hospitals and local authorities. Additional information was also collected via voluntary questionnaires sent to casualties where appropriate.

OTS data are now stored in the RAIDS database, along with data from other studies and can be accessed with permission from the DfT. It is restricted by password controls as well as monitoring who has accessed specific data. Access can only be granted when it is clear that it is for the purposes of genuine research with the intent to improve road safety.

2.4.4.2. UK Road Accident In-Depth Studies (RAIDS)

The RAIDS project started in 2012 and is a combination of earlier studies, including OTS, Co-operative Crash Injury Study (CCIS), Heavy Vehicle Crash Injury Study (HVCIS), Fatal files and STATS19 (accident data for all road accidents in GB), and current data collection of road traffic collisions investigated by the UK's Transport Research Laboratory (TRL) in Wokingham and the Transport Safety Research Centre (TSRC), based at Loughborough University. The project is funded by the Department for Transport, where the focus of each investigation is how a road related injury occurred rather than how a road accident occurred.

Two types of investigation are performed, the methodologies having been based on those of previous studies:

- An investigation following the same procedure as OTS, including questionnaires sent to appropriate accident participants.
- A retrospective investigation that examines vehicles recovered from the crash site where there was serious damage, or where there was some recorded casualty that required hospital treatment.

As there were only a small amount of new data available in RAIDS at the time of writing it was decided that an analysis of the OTS data would be more appropriate.

2.4.4.3. OTS analysis

The OTS data set contains 4,744 accidents, of which 4,614 involve at least one occupant causation factor and of which 603 list some distraction as a causation factor. Table 8 shows the distribution of casualties by severity for all accidents studied. Of the 3,861 casualties recorded, approximately 3% of all casualties were fatal, while 20% were seriously injured. The smaller number of casualties as opposed to accidents implies that there was not a casualty associated with every accident. However, multiple casualties occurred in some accidents.

Table 8: Total number of casualties by severity in OTS

	Severity			Total
	Fatal	Serious	Slight	
Number of casualties	119	778	2,964	3,861
Proportion of casualties	3%	20%	76%	100%

The results are similarly distributed in Table 9, which displays accidents by severity where there was at least one occupant causation factor, as in Table 8, with results making up approximately 98% of the initial table. This indicates that the majority of accidents occur due to occupant causation instead of another causation factor, such as vehicle malfunction, environment or infrastructure.

Table 9: Total number of casualties by severity involved in an accident with at least one occupant causation factor

	Severity			Total
	Fatal	Serious	Slight	
Number of casualties	116	764	2,912	3,792
Proportion of casualties	3%	20%	76%	100%
Percentage of all casualties with at least 1 occupant causation factor	98%	98%	98%	98%

Table 10 shows that distraction appears to make a large contribution to casualty figures, with 16% of all casualties and 19% of fatal casualties being involved in a distraction-related collision. This matches with the literature where there were estimates that distraction played a role in 5% to 25% of all road traffic accidents (DaCoTA, 2012).

Table 10: Total number of casualties by severity involved in an accident where a form of distraction was a contributing factor

	Severity			Total
	Fatal	Serious	Slight	
Number of casualties	23	101	505	629
Percentage of all casualties where distraction was a contributing factor	19%	13%	17%	16%

Car passengers made up the majority of distraction related casualties, as the majority of road traffic is made up of cars. Of the remaining vehicle types the majority are made up of Light Goods Vehicles, Motorcycles and Pedestrians, as shown in Table 11.

Table 11: Total number of casualties by severity and vehicle type involved in an accident where distraction was a contributing factor

		Severity			Vehicle Totals
		Fatal	Serious	Slight	
Vehicle type	Car	14	65	422	501
	Light Goods	2	2	28	32
	Heavy Goods	2	1	7	10
	Bus	0	0	4	4
	Motor Cycle	1	16	23	40
	Pedal Cycle	1	4	11	16
	Pedestrian	3	13	10	26
Total		**23**	**101**	**505**	**629**

The majority of casualties having distraction as a contributing factor are between the ages of 25-59 years (Table 12), although this is to be expected as a larger amount of the population is between these ages. However, with 46% of casualties being younger or older than this age range, it is clear that distraction can also have serious consequences for children, teenagers, young adults and older adults 60 years and above.

Table 12: Total number of casualties involved in an accident where distraction was a causation factor by severity for each age group

		Severity			Totals	Proportion
		Fatal	Serious	Slight		
Age (years)	0-16	1	13	45	59	9%
	17-24	4	24	96	124	20%
	25-59	9	42	289	340	54%
	60+	9	22	75	106	17%
Total		**23**	**101**	**505**	**629**	**100%**

Table 13 indicates the number of casualties that were associated with different road users who were distracted and caused accidents. Again car occupants make up the majority of casualties although this is expected due to the larger proportion of cars on the road. The second half of the table shows that many more casualties came about as a result of someone else being distracted as opposed to being "self-inflicted".

Table 13: Total number of casualties involved in an accident involving distraction as a causation factor by severity per road user group

		Severity			Total
		Fatal	Serious	Slight	
Person who caused accident while distracted	Car occupant	7	24	141	172
	Cyclist	0	2	3	5
	Heavy Goods Vehicle occupant	1	0	3	4
	Light Goods Vehicle occupant	1	1	9	11
	Motorcyclist	1	8	6	15
	Pedestrian	1	7	5	13
	Total	**11**	**42**	**167**	**220**
Others injured as a result of distracted behaviour	Bus occupant	0	0	4	4
	Car occupant	7	41	283	331
	Cyclist	1	2	8	11
	Heavy Goods Vehicle occupant	1	1	4	6
	Light Goods Vehicle occupant	1	1	17	19
	Motorcyclist	0	8	17	25
	Pedestrian	2	6	5	13
	Total	**12**	**59**	**338**	**409**

Table 14 and Table 15 show the split of the types of distraction that were listed as the contributing factor. Table 14 shows how each casualty was associated with a distraction event. It can be seen that a larger proportion of distraction events occurred inside the vehicle. The reason for there being 679 cases as opposed to the previously seen 629 is that the two factors are not mutually exclusive, meaning that one road user can have both factors; there are 50 casualties with both factors recorded.

Table 14: Total number of casualties involved in an accident where distraction was a causation factor by severity and basic type of distraction

		Severity			Total
		Fatal	Serious	Slight	
Distraction Type	Outside vehicle	8	29	159	196
	Inside vehicle	18	74	391	483
	Total	**26**	**103**	**550**	**679**

Table 15 shows the split at the individual occupant level, allowing for greater detail into the distraction type. The table has been organised to show different distraction factors that are either related to electronic devices or are a competing driving activity (i.e. looking at a map) with all other distractions grouped into "Other distractions". "Gave audible warning before collision" has been recorded as a type of a distraction; it is unclear if a road user was distracted by the warning or if they gave the warning to another distracted road user. Overall, these factors of interest do not appear to have a large impact on casualty rates, although there is a large proportion of the casualties with an unknown distraction type and therefore these results could be underreported.

Table 15: Total number of casualties involved in an accident where distraction was a causation factor by severity and type of distraction

		Severity			Total
		Fatal	Serious	Slight	
Distraction Type	Listening to CD or Walkman	0	3	8	11
	Adjusting radio or changing CD	0	0	2	2
	Using navigation system	0	1	1	2
	Gave audible warning before collision	0	0	2	2
	Reading or looking at e.g. map	0	0	1	1
	Talking on a mobile phone	0	3	6	9
	Other distractions	1	34	201	236
	Actions Unknown	13	19	153	185
	Total	**14**	**60**	**374**	**448**

2.4.4.4. The CARE database

The Common Accident Data Set (CADaS) was set up with a view of improving the accident data compatibility throughout Europe, to be used by any EU country that wishes to update their national road accident collection system (NTUA, 2008). This is done by having countries submit their national accident data voluntarily and the data being then stored together in a structured database called CARE. Of the data stored in the resulting database, there were only instances of road accidents with a type of distraction as a contributory factor for four countries: Hungary, Iceland, Luxembourg and Switzerland. The only types of distraction recorded are cases related to electronic devices.

The CADaS glossary states that 'Distraction by Electronic Device':

> "Indicates whether a driver's or pedestrian's attention was distracted by an electronic device. The on-going increase of the use of mobile phone, navigation devices, televisions and other electronic devices in vehicles implies the inclusion of this variable in order to examine the relation of electronic device use while driving, with road accidents. If the road user was not a driver or a pedestrian this variable is not applicable." (Saurabh, 2013).

The categories involved are 'telecommunication device' and 'other electronic device'.

Each country's data have been investigated individually to observe what effects electronic devices may be having on road safety.

Hungary

In Hungary, there has been a steady decline in the number of accidents since 2006 (see Figure 5), until 2013 when there was a slight rise. This would point towards a general improvement in road safety in Hungary in recent years but it is not possible to tell from these data alone what may have caused this, especially as there is no measure of exposure.

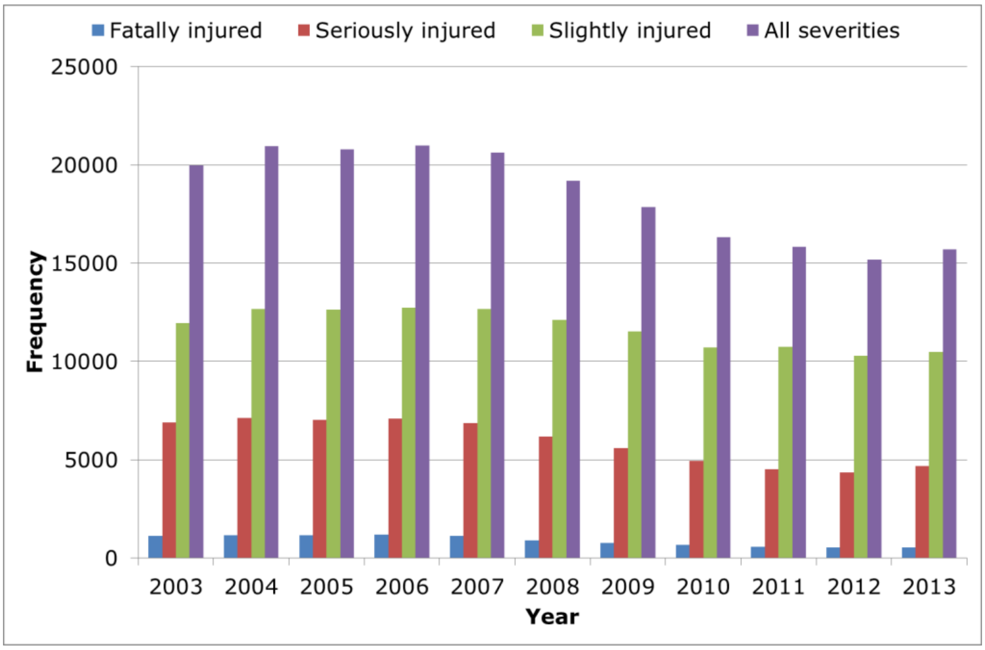


Figure 5: Total number of accidents by severity in Hungary

Data on distraction by electronic devices are only available for Hungary since 2010. It is not possible to identify the impact of telecommunication devices specifically. As the number of years since distraction has been recorded is so few, it is not possible to determine any trends in the data. Nevertheless, at this early stage and on the basis of data collected it appears that distraction by an electronic device is a contributory factor in around 2% of injury crashes in Hungary (see Figure 6).

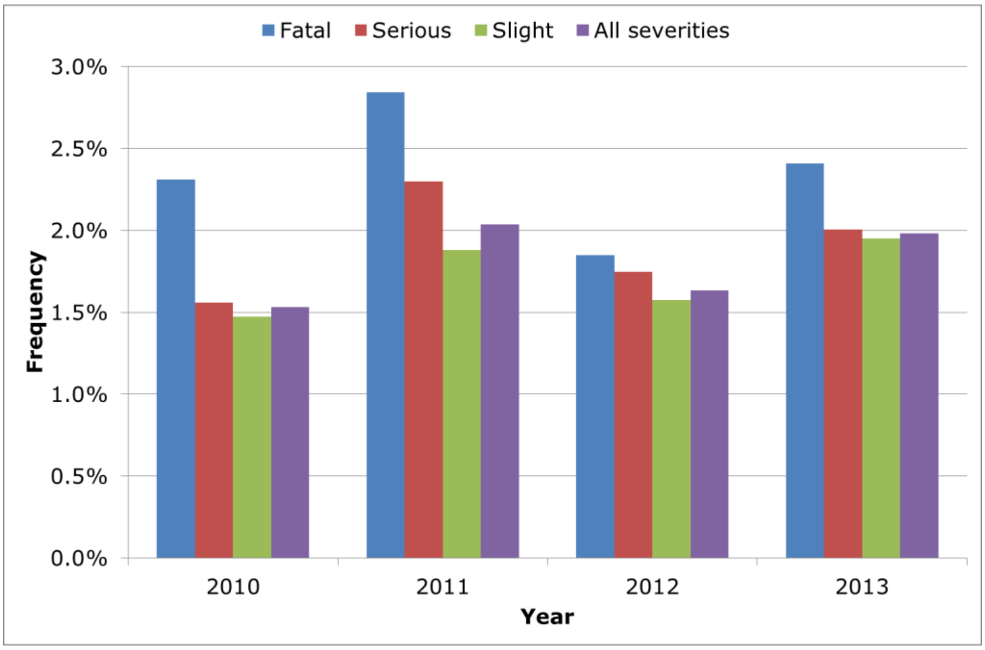


Figure 6: Percentage of accidents by severity where distraction by electronic device was a contributing factor in Hungary

Iceland

Since 2008 there had been a steady decrease in casualty accidents until 2013 where there was a sudden rise. The numbers are not particularly large, due to the small population of Iceland; therefore it was necessary to group the figures into three-yearly groups to get a more robust representation of these trends, as seen in Figure 7.

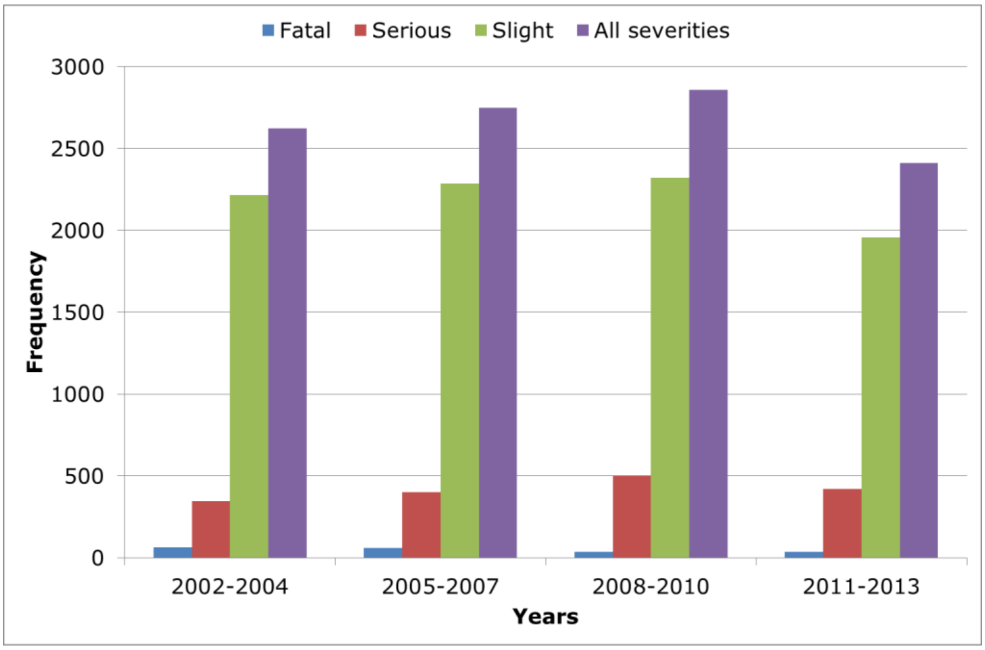


Figure 7: Total number of accidents by severity in Iceland

In terms of electronic devices, Iceland's data only contain information on mobile devices in accidents. It can be seen in Figure 8 that there do not appear to have been any fatal accidents involving distraction caused by a mobile device since at least 2002. The other severities also contain quite low frequency rates, relative to the data reported from Hungary.

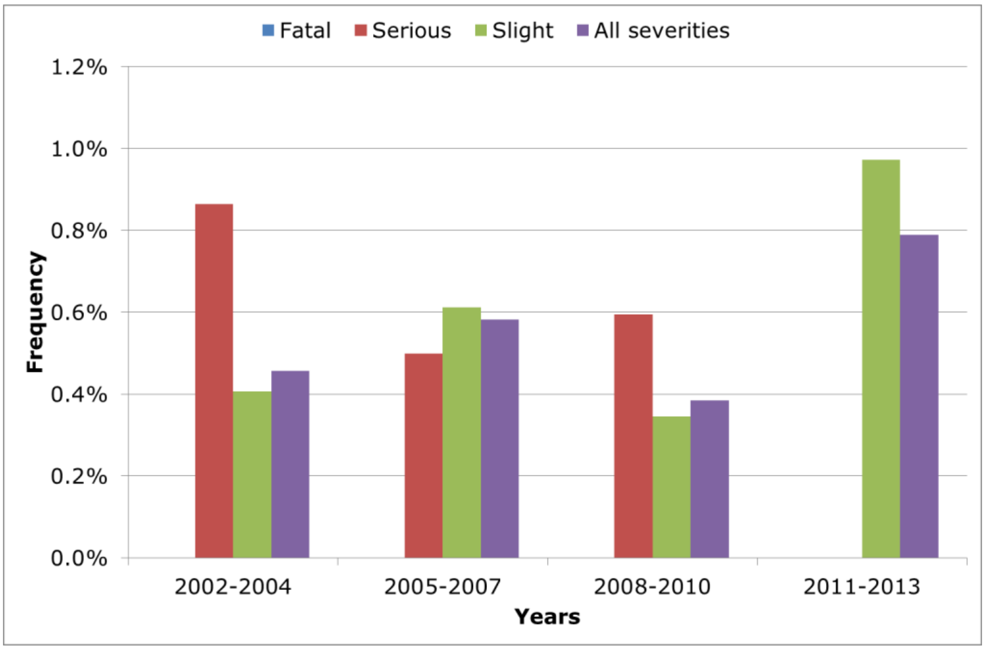


Figure 8: Percentage of accidents by severity where distraction by electronic device was a contributing factor in Iceland

Luxembourg

Accidents in general in Luxembourg appear to have increased in frequency from 2004 to 2007 and then decreased until 2009. This is followed by a rise in frequency to 2012, after which there was a decline between 2012 and 2013. These trends can be seen in Figure 9, and may be attributed to the relatively small number of accidents that are recorded in Luxembourg.

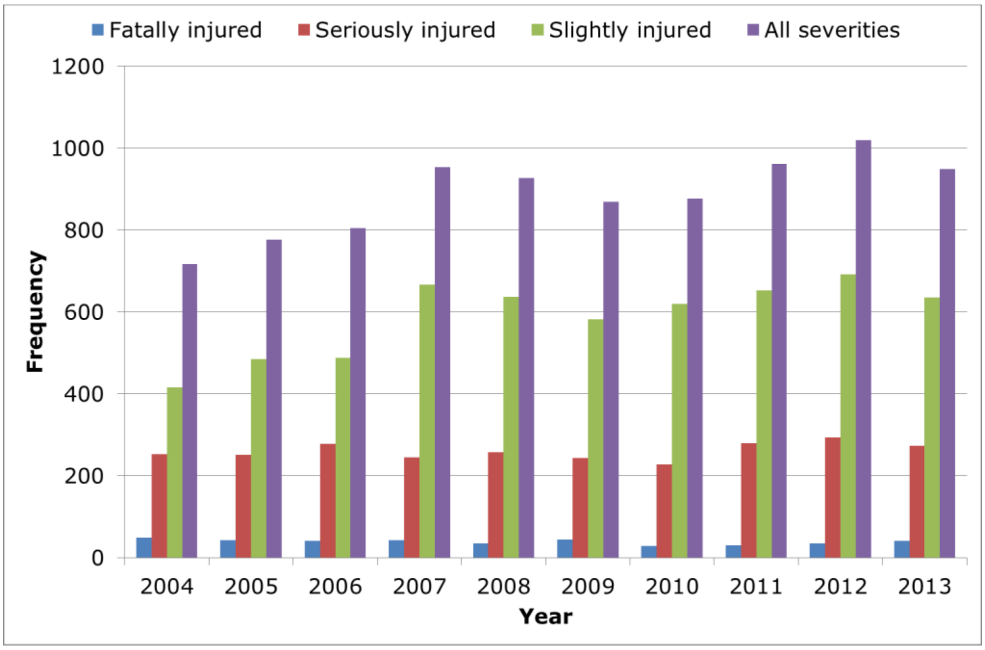


Figure 9: Total number of accidents by severity in Luxembourg

However, it is not determinable as to what impact distraction by electronic devices has had on this overall number. Figure 10 shows the percentage of accidents by severity attributed to distraction by some electronic device but as there are only 2 years' of these data no trend is visible. Despite this there is potentially an impact on the fatality rate as just less than 5% of fatalities in 2013 were recorded with distraction by electronic device as a contributory factor, with all cases being related to a telecommunication device.

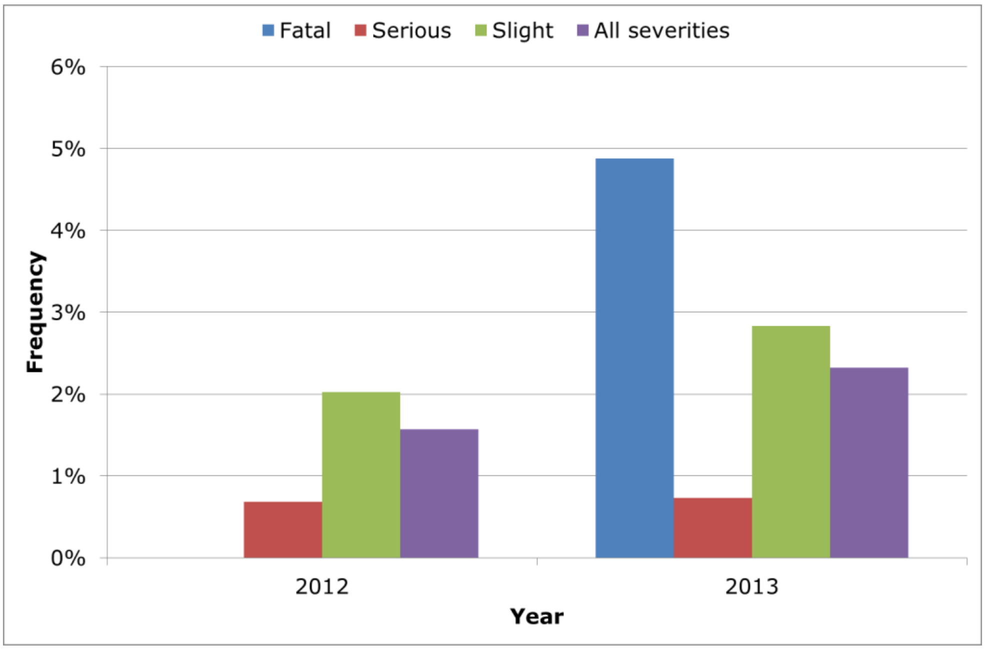


Figure 10: Percentage of accidents by severity where distraction by electronic device was a contributing factor in Luxembourg

Switzerland

As can be seen in Figure 11, the numbers of accidents in Switzerland are generally reducing each year for all severities. This would imply that road safety is improving in Switzerland, although there was a slight increase in 2007.

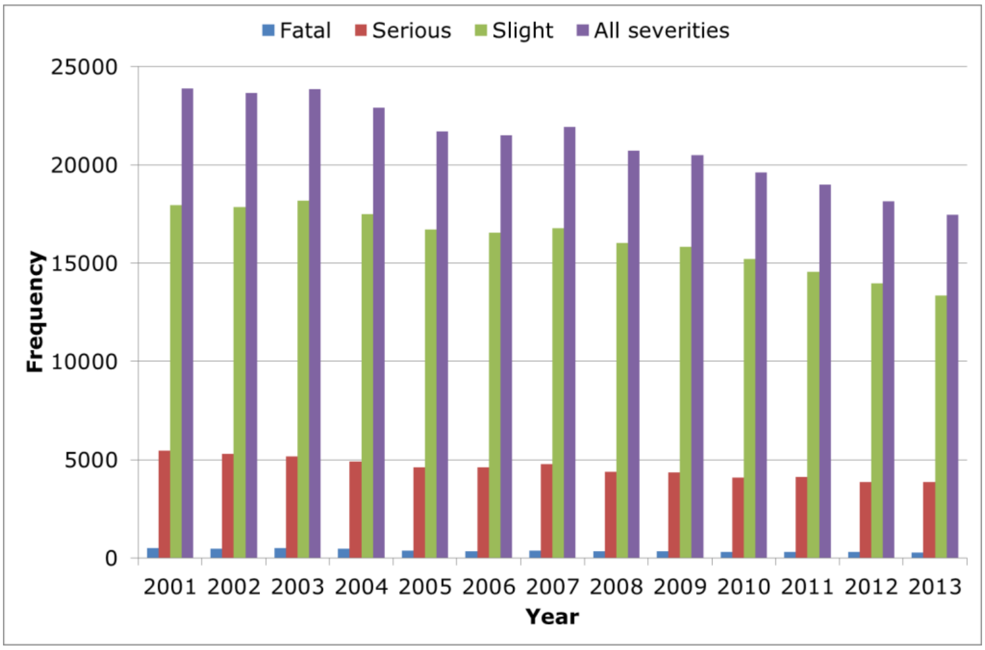


Figure 11: Total number of accidents by severity in Switzerland

It can be seen from Figure 12 that the numbers of accidents where distraction by electronic device is a contributing factor has fallen in Switzerland since 2001, although there was an increase between 2008 and 2001. These figures relate to all types of electronic device. Although accident statistics were collected in 2004, there appears to be no information regarding distraction as a contributory factor for that year.

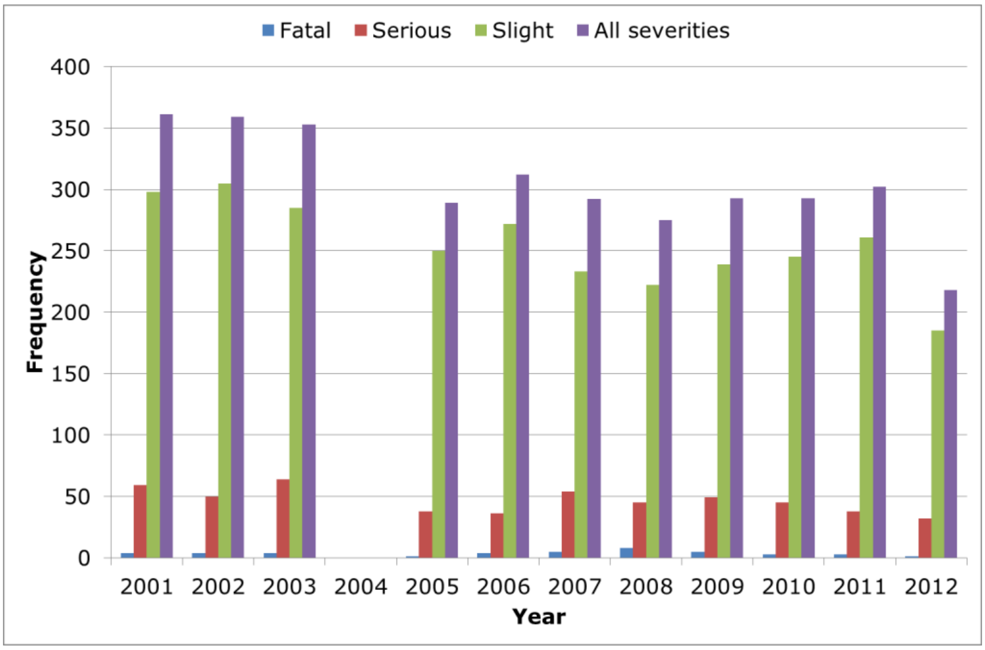


Figure 12: Number of accidents by severity where distraction by electronic device was a contributing factor in Switzerland

The number of accidents where distraction by a mobile telecommunication device is a contributory factor has increased relative to the overall number of accidents. Figure 13 shows this. This highlights that, despite the downward trend in road accidents in Switzerland, accidents involving mobile devices appear to be becoming a larger problem.

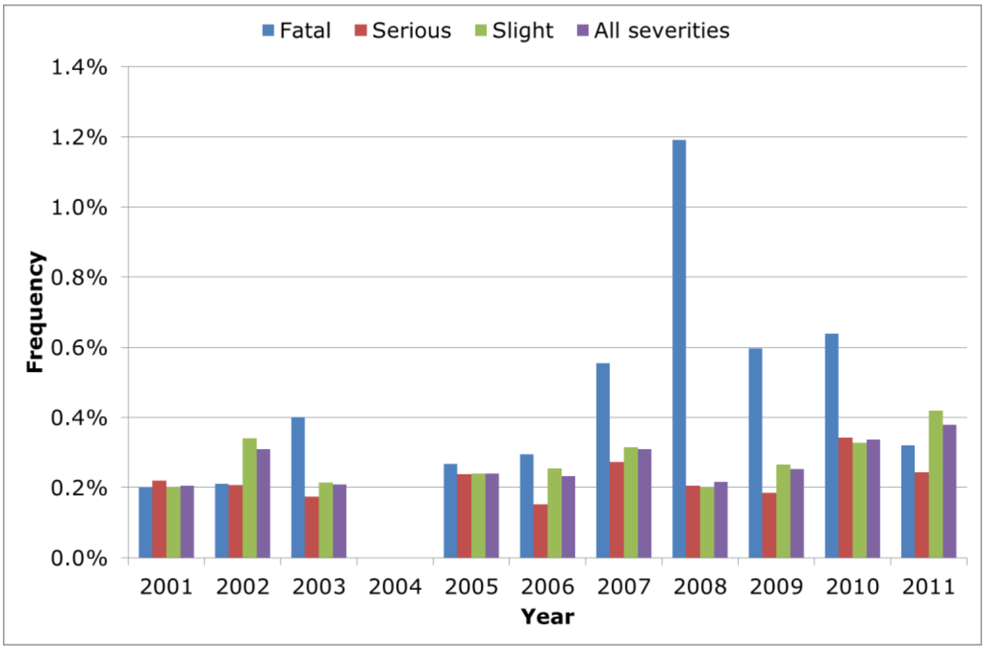


Figure 13: Percentage of accidents by severity where distraction by telecommunication device was a contributing factor in Switzerland

It should also be noted that the percentage of accidents where distraction by an electronic device is a contributing factor never exceeds 0.4% for the total number of telecommunication related accidents and never exceeds 1.2% for fatal accidents.

2.4.5. Additional European data

Two additional data sources were investigated and identified as potential useful sources of data, although it was not possible to investigate the data from these sources within the project. These are the German In-depth Accident Study (GIDAS) based on a subset of accidents occurring in Hanover and Dresden, and the in-depth database collected as part of the EU SafetyNet project covering 1,005 accidents in six European countries.

It is likely, given the relatively small coverage of these datasets and the published research which has been described above, access to these datasets would not improve our understanding of distraction accidents in Europe. The background to these datasets is described in Appendix B.

2.5. Summary of the size and nature of the problem

The aim of the work reported in this chapter was to determine, as far as possible, the size of the problem and characteristics of distraction-related events in the EU, both in terms of the literature on distraction and accident data, and in terms of current and future technological developments that might impact on the issue.

In this section we summarise the main findings under individual sub-headings.

2.5.1. Distraction has an impact on the performance of all road users

It is evident that distraction caused by the proliferation of mobile electronic devices has the potential to be a major road safety risk to road users in Europe. There is abundant evidence that distraction effects occur in drivers, and also in vulnerable road user groups such as pedestrians and cyclists. Some similar outcomes are observed between these groups (for example car drivers and cyclists have been observed to have less lateral control and less processing of stimuli in their periphery when distracted) and performance on even apparently very simple behaviours (such as crossing behaviour in pedestrians) can suffer as a result of distraction.

2.5.2. It is tasks, not technologies, that provide an explanation of impact

Work to date suggests that the effect of technologies to impact on safety can be best understood by considering the tasks they require of the road user to function. The performance of these tasks will only impact on safety where they are not conducive with the environmental context within which the user is engaging. For drivers, this appears to include at least the amount of time the driver must look away from the road (Klauer et al., 2014; Simons-Morton et al., 2014; Victor et al., 2014), and probably some aspects of cognitive load in high-demand situations (e.g. Burns et al., 2002).

Basacik and Stevens (2008) note that distraction-related crash risk is probably a function of:

- Timing – e.g. coinciding with an unexpected event is more critical in a high workload situation, such as when negotiating a junction
- Intensity – e.g. texting requires more resource than listening to the radio
- Resumability – the extent to which tasks can be dropped and re-started efficiently
- Frequency – actions repeated more often are more likely to coincide with a critical event
- Duration – duration of the distraction will increase the probability of the distraction coinciding with a critical situation
- Hang-over effect – the lingering cognitive or emotional residue beyond task completion.

It is likely that measuring distraction-related crash risk in future will rely on measurement of tasks rather than device-use *per se*; this has implications for how accidents are investigated and coded, for example.

2.5.3. A common definition of distraction is required

A major barrier for comparing studies and data has been the inconsistent use the terms 'distraction' and 'inattention'. A common definition is desirable. Recent studies such as Engström et al. (2013) and Regan et al. (2011) have sought to draw together theory and evidence to provide such a framework and these should be embraced. While these studies are based upon the perspective of the driver, such is the human element of inattention and distraction caused by a secondary task that the principles can be broadly applied to all road users. Further work should seek to develop these frameworks for application to other road users specifically.

For the purposes of the current project the theoretical underpinnings of Engström et al. can assist with understanding the perspective of attention as all encompassing, representing attentional failures as part of a road user(-vehicle)-environment system in which new technologies are integrated.

To ensure consistency throughout the project the following definitions are proposed (these are also revisited in the recommendations):

Driver inattention: "…inattention occurs when the driver's allocation of resources to activities does not match the demands of activities required for the control of safety margins." (Engström et al., 2013, p38).

Driver distraction: "…where the driver allocates resources to a non-safety critical activity while the resources allocated to activities critical for safe driving do not match the demands of these activities." (Engström et al., 2013, p35).

Activities critical for safe driving: "…those activities required for the control of safety margins…" (Engström et al., 2013, p17).

2.5.4. An estimate of the size of the problem in the EU

Reliably relating distraction with crash risk in the EU (or worldwide) is problematic and current estimates of the proportion of accidents that involve distraction vary widely. The reasons for such variation can be largely explained by the following key limitations:

- There is no agreed definition of inattention or distraction when collecting accident data in the EU. This includes contributory factor data being collected as either distraction or inattention with no distinction being made and/or no distinction between types of distraction (e.g. use of non-driving related electronic equipment like mobile phones versus eating or drinking while driving).
- Too few countries in the EU collect data where distraction is recorded as a contributory factor.
- Distraction is a very difficult contributory factor to reliably record during post-accident data collection.
- The proliferation of mobile communication and in-vehicle technologies into the mass market is a recent phenomenon and will have varied in market penetration from country to country across the EU. It is possible that studies are relying on data that may not reflect current conditions and conditions that are not comparable from country to country.

By the definition applied here, a high proportion of accidents will involve some form of inattention; inattention occurs when the driver's allocation of resources does not match the demands required for the control of safety margins. Naturalistic studies provide some support for this assertion with one such study in the USA finding that 78% of crashes and 65% of near-crashes involved the driver not allocating their visual resources in the direction of the conflict (Dingus et al., 2006). This study further reports that the driver being occupied by things other than the driving task (e.g. using a mobile phone) was a factor in 24% of crashes; being occupied by non-critical driving related matters (e.g. changing climate control) was a factor in 19% of crashes.

An in-depth accident study in Europe meanwhile suggest that distraction is a contributory factor for at least one road user in 21% of accidents; inattention is recorded as a contributory factor in a further 11% (Talbot et al., 2013)[2].

Taking all these findings together, the current estimate for the impact of road user distraction on accidents in the EU is that it is a contributory factor in around 10-30% of

[2] The definitions used for coding were: Distraction – the performance of a task is suspended because the person's attention was caught by something else or the attention has shifted; Inattention - Low vigilance due to loss of focus.

road accidents[3]. Current limitations mean that this estimate of distraction related accidents across Europe currently lacks validity and reliability until supported by coordinated data collection.

The influence of technology and electronic devices on distraction-related accidents in Europe is especially difficult to determine as no literature or data could be found to reliably quantify this. Although numerous reports were found containing the frequency of mobile phone and other electronic device use in road traffic, a reliable relationship of use with distraction and accident data is non-existent. This is due to a lack of national accident data collection systems coding distraction as a contributory factor at all; where it is coded, it is not defined in such a way that enables meaningful research and analysis of this factor.

[3] The data used in Talbot et al. (2013) were derived from only six countries in Europe (Italy, Germany, Sweden, Norway, UK, Netherlands) and may not be representative of the EU as a whole.

3. UNDERSTANDING DRIVER DISTRACTION AND THE SIZE AND NATURE OF THE PROBLEM – TECHNOLOGICAL DEVELOPMENTS

3.1. Aim

This chapter further examines the nature and size of the distraction problem, by providing a review of current and future technological developments related to road user distraction, and an analysis and summary of their likely impact on the scope of distraction-related road safety events in the EU. A review of the literature and of expert opinion was used to identify technological developments that have the potential to contribute in a positive or negative way to user distraction.

Technological developments in this case are not concrete ITS devices, products or services, but developments in technology that underpin or will likely underpin future ITS devices, products and services. Identifying and describing these technological developments, and estimating their expected impact on road user distraction, provides an overview of mid- and long-term development of ITS products, devices and services in tems of road user distraction, and helps to further understand the scale of the problem.

The methodology and findings from this review are described in Sections 3.2 and 3.3.

A summary of the findings from this chapter is presented in Section 3.4.

3.2. Methodology

For each technological development identified, the following things were described: key deployment pre-conditions, drivers and constraints. In addition a quantitative expert assessment of the potential to contribute to or mitigate user distraction was made (for each distraction type and road user type).

To arrive at a well-founded assessment of the potential impact of each technological development, the impact of each was classified using the ordinal scale listed in Table 16.

The classification was carried out for each:

- Distraction type – Visual, Auditory, Biomechanical, Cognitive
- Road user type – Drivers in private vehicles, Professional drivers, Motorcyclists, Pedestrians, Cyclists, Children, Elderly

For the category ‘Children’ it is assumed these are pedestrians younger than 16 years, that are easily distracted and do not always have a good sense of traffic dangers (Freeman et al., 2012; Hoekstra et al., 2013; Stelling & Hagenzieker, 2012).

For the category ‘Elderly’ it is assumed these are pedestrians older than 64 years with limited hearing and sight impairments, somewhat slower reaction and somewhat reduced agility (Freeman et al., 2012; Elslande et al., 2012).

End-user devices and ITS services (both current and expected) were identified and described as input to later parts of the project which focused on countermeasures to distraction.

Table 16: Impact classes

Value	Name	Description impact rating scale
3	Strong reduction	Significantly reduces user distraction
2	Moderate reduction	Reduces user distraction
1	Minor reduction	Slightly reduces user distraction
0	Neutral	Has no effect on user distraction
-1	Minor increase	Slightly increases user distraction
-2	Moderate increase	Increases user distraction
-3	Strong increase	Significantly increases user distraction
-	Not applicable	Cannot be used by user group, or applied to influence a specific distraction type

3.3. Systems that may cause or reduce distraction

3.3.1. Technological developments

Based on expert input and a literature review, technological developments that have the potential to contribute in a positive or negative way to user distraction were identified. This resulted in the following list of technological developments (Table 17).

For each technological development key deployment pre-conditions, drivers and constraints were described, which were then used in the analyses in later parts of the project which examined countermeasures (Appendix C, Table C1).

Table 17: Technological developments used in the assessment

No.	Name	Description
1	Sensor data	Increasing availability of sensor data, e.g. GNSS, RADAR, IR and visible light imaging, accelerometer, electronic compass and gyroscope
2	Non-flat display technologies	Display technologies that allow curved display surfaces
3	Tactile sensor technology	Touch screens (usually) situated in the mid-console, and other touch sensitive HMI components
4	Dynamic dashboard	Dynamic dashboard display
5	Head-up display	Projection of information on top of the real world by projection on the windscreen, in glasses or goggles, or directly onto the road user's retina
6	Night vision	A night vision system is a system using a Thermographic camera to increase a road user's perception and seeing distance in darkness or poor weather
7	Haptic/tactile feedback	Vibration, counter force, body pressure or tapping in steering wheel, seats and other HMI components
8	Increased vehicle connectivity	Data connections of vehicles to other vehicles, roadside equipment and cloud services
9	Intra-nomadic-vehicle connectivity	Increased connectivity between nomadic devices (smartphones, PNDs) in the vehicle and vehicle systems, e.g. through MirrorLink, Apple Carplay, Android Auto
10	Extra-nomadic-vehicle connectivity	Increased connectivity between smartphones outside vehicles and vehicle systems, e.g. through WIFI(-p), EDGE network, other radio links, used in particular to limit collision risks and focus driver attention to VRU.
11	Biometry	Use of sensor data to detect road user condition. e.g. drowsiness or distraction detection for car drivers, and road user specific HMI adaptation, e.g. automatic seat adjustment
12	Voice recognition	Improved speech recognition in the vehicle
13	Virtual reality	Perception methods to create awareness of visually obstructed objects, such as road users around a corner
14	Artificial intelligence	Machine learning technology enabling human-like interpretation of data. e.g. to detect anomalies in own or other vehicle's driving behaviour
15	Conditional automation of driving tasks	Automation of driving tasks to SAE level 3 (SAE 2014): the vehicle drives itself, but the human driver is expected to respond appropriately to a request to intervene by the vehicle.

No.	Name	Description
16	High automation of driving tasks	Automation of driving tasks to SAE level 4 (SAE 2014): the vehicle drives itself under all conditions, but the driver can intervene in the driving tasks.
17	Full automation of driving tasks	Automation of driving tasks to SAE level 5 (SAE 2014): the vehicle drives itself under all conditions.

3.3.2. Impact by distraction type

For each distraction type an assessment was carried out by experts at Rapp Trans NL supported where possible by findings from the literature review and subsequently validated by experts at TNO to indicate in relative terms the expected impact of each technological development (Table 18). The reasoning for each rating is included in Appendix C (Table C2).

The overview suggests that most of the technological developments have the potential to reduce some aspects of distraction; this is dependent on the exact implementation of the system's functionality and on the system's interaction with the road user and the chosen modalities to convey the information.

Because technological developments are quite abstract notions, the literature review did not produce clear-cut impact levels per technological development, but rather provided the basic indicators to support the impact assessment. E.g. there is ample evidence that mechanical interaction of drivers with mobile devices produces one of the most dangerous forms of road user distraction from literature. Hence technologies that will likely reduce the need for mechanical interaction, such as improvements in tactile sensor and speed recognition technology, can be assumed to reduce biomechanical road user distraction.

It is expected that future technologies will make more data accessible, give more accurate information, provide better information tailoring, or more effective conveyance of information to the road user. It should be noted that this potential will only be capitalized upon if these technologies are properly implemented. If poorly implemented most technologies also have the potential to increase user distraction.

Table 18: Classification of technological development impact per distraction type

No	Name	Visual	Auditory	Biomechanical	Cognitive
1	Sensor data	-	-	-	1
2	Non-flat display technologies	-1	0	-	0
3	Tactile sensor technology	-1	-1	1	0
4	Dynamic dashboard	1	0	0	0
5	Head-up display	1	0	0	0
6	Night vision	-1	0	0	0
7	Haptic/tactile feedback	0	0	1	0
8	Increased vehicle connectivity	-1	-1	-1	1
9	Intra-nomadic-vehicle connectivity	1	1	1	-1
10	Extra-nomadic-vehicle connectivity	-1	-1	0	1
11	Biometry	-	-	-	2
12	Voice recognition	1	-1	2	1
13	Virtual reality	-1	-1	0	1
14	Artificial intelligence	-1	-1	0	2
15	Conditional automation (SAE=3)	-1	-1	0	2
16	High automation (SAE=4)	0	0	-1	2
17	Full automation (SAE=5)	0	0	0	3

Some technologies can be combined to cancel out specific drawbacks, or to reinforce a benefit. For example by combining the latest sensor data technology and artificial intelligence it is possible to identify and classify road users in the vicinity of a vehicle and determine the potential collision risk. Night vision and a head-up display can be used to focus the driver's attention to the most relevant visual cues.

Technological developments that reduce visual and biomechanical distraction are expected to have the highest impact on road user distraction overall. These are improvements in tactile sensor, dynamic dashboard, head-up display, haptic/tactile feedback technologies.

Developments in data communication technology that provide better connectivity between vehicles and nomadic devices (mobile/smart phones, navigation devices, audio players) can indirectly reduce road user distraction as they have the potential, if properly implemented, to make interaction with nomadic devices much less distracting.

An increase in automation of the driving task will have an effect on issues with distraction. For example partial automation of driving tasks will allow a driver to focus on safety-related aspects of driving (i.e. a cognitive benefit), but it can also draw attention away from the traffic situation if the driver is uncertain about the level of automation in the vehicle. At the same time a higher automation level will allow for more infotainment and other non-driving related activity.

Caution should be taken in the interpretation of the ratings in the overview. The ratings do not provide a factual measure for the impact potential per technological development. They should be interpreted as a general indication of the technology’s potential to contribute to user distraction, in the opinion of the team of experts who provided the ratings.

3.3.3. Impact by road user type

For each technological development a similar assessment was made of the impact for different road users (

Table 19). The reasoning for each rating is included in Appenidix C (Table C3).

The assessment suggests that all road user types can potentially benefit from the technological developments. The potential benefits seem to be the highest for vehicles and much less for cyclists, and pedestrians. This is mainly because vehicles in general are more suited as a deployment platform. Vehicles can provide the physical space, stability, and the continuous power supply most technological developments require.

Technological developments that directly limit the need for mechanical interaction between drivers and their vehicle, and that allow for a more efficient presentation of information from the vehicle to the driver (e.g. dynamic dashboards, head-up displays, haptic/tactile feedback, biometry and voice recognition) have the highest potential to reduce road user distraction for drivers of cars, lorries and motorcycles. Improvements in connectivity between a vehicle and nomadic devices inside the vehicle also have the potential to reduce the need for mechanical interaction between drivers and nomadic devices, and therefore are also expected to have a relatively high potential to reduce distraction in vehicle drivers.

Pedestrians, cyclists, children and the elderly are expected to benefit (in terms of reduced distraction) mostly from technological developments that reduce or cancel the need to interact visually with the nomadic devices they carry (e.g. haptic/tactile feedback technologies).

As previously noted, caution should be taken in the interpretation of the ratings in the overview. The ratings do not provide a factual measure for the impact potential of technological developments per road users. They should be interpreted as a general indication of the technology’s potential to contribute to user distraction per road user type, in the opinion of the experts providing the ratings.

Table 19: Classification of Technological Development impact by road user type

No	Name	Drivers in private vehicles	Professional drivers	Motorcyclists	Pedestrians	Cyclists	Children (pedestrians)	Elderly (pedestrians)
1	Sensor data	1	1	1	-1	-1	-1	-1
2	Non-flat display technologies	-1	-1	1	1	1	-1	-1
3	Tactile sensor technology	-1	-1	-2	-2	-2	-2	-2
4	Dynamic dashboard	2	2	2	-	-	-	-
5	Head-up display	2	2	1	0	0	-1	-
6	Night vision	-1	-1	-1	-1	-1	-1	-1
7	Haptic/tactile feedback	2	2	3	1	2	1	1
8	Increased vehicle connectivity	2	2	2	-	-	-	-
9	intra-nomadic-vehicle connectivity	1	1	1	-	-	-	-
10	extra-nomadic-vehicle connectivity	0	0	0	1	1	1	1
11	Biometry	2	2	1	0	0	0	0
12	Voice recognition	1	2	3	0	0	0	0
13	Virtual reality	0	0	0	0	0	0	0
14	Artificial intelligence	1	1	1	0	0	0	0
15	Conditional automation (SAE=3)	1	1	-	-	-	-	-
16	High automation (SAE=4)	2	2	-	-	-	-	-
17	Full automation (SAE=5)	3	3	-	-	-	-	-

3.3.4. Knowledge base and gaps

Sixty documents, presentations and publications related to user distraction were collected. Based on the qualifying criteria for the knowledge base shown in Table 20, a number of these documents were classified as irrelevant or too old.

Table 20: Qualifying criteria for Task 2 literature

	Criteria
Literature types	Scientific and market research, guidelines, best practices, regulations, visions on market and technological developments
Topic	Interaction with and distraction by devices and services used in traffic, for any modality (car, pedestrian, bicycle, etc.), on any type of device (in-dash, nomadic)
Date	Within the last 10 years
Geographical scope	'1st world' countries worldwide

In total 31 documents were taken forward for full review and included in the knowledge base.

From these 31 documents all findings that were judged as having some relevance to the impact of technological developments on user distraction in traffic were listed, and then mapped to combinations of technological development and distraction types, and technological development and road user types. Table 21 provides an overview of the results (Tables C4 and C5 in Appendix C provide the detailed results).

The resulting cross-tables indicate that much information is available on the use of mobile and smart phones for different uses (calling, texting, and varying uses of internet services such as social media and browsing) in vehicles and by cyclists and pedestrians.

As one would expect, virtually no information on user distraction is available on technology that has not yet been widely deployed such as voice recognition and the automation of driving tasks.

Table 21: Availability of research literature (red: none/minimal, yellow: some, green: sufficient)

No	Name	Visual	Auditory	Biomechanical	Cognitive		Drivers in private vehicles	Professional drivers	Motorcyclists	Pedestrians	Cyclists	Children	Elderly
1	Sensor data	red	red	red	red		red	red	red	red	red	red	red
2	Non-flat display technologies	red	red	red	red		red	red	red	red	red	red	red
3	Tactile sensor technology	red	red	red	red		red	red	red	red	red	red	red
4	Dynamic dashboard	red	red	red	red		red	red	red	red	red	red	red
5	Head-up display	yellow	red	red	red		red	red	red	red	red	red	red
6	Night vision	red	red	red	red		red	red	red	red	red	red	red
7	Haptic/tactile feedback	red	red	red	red		red	red	red	red	red	red	red
8	Increased vehicle connectivity	red	red	red	yellow		red	red	red	red	red	red	red
9	intra-nomadic-vehicle connectivity	yellow	yellow	green	green		green	green	red	green	green	red	red
10	extra-nomadic-vehicle connectivity	red	red	red	yellow		red	red	red	red	red	yellow	yellow
11	Biometry	red	red	red	red		yellow	red	red	red	red	red	red
12	Voice recognition	yellow	red	yellow	yellow		red	red	red	red	yellow	red	red
13	Virtual reality	red	red	red	red		red	red	red	red	red	red	red
14	Artificial intelligence	red	red	red	yellow		red	red	red	red	red	red	yellow
15	Conditional automation (SAE=3)	red	red	red	yellow		red	yellow	red	red	red	red	red
16	High automation (SAE=4)	red	red	red	red		red	red	red	red	red	red	red
17	Full automation (SAE=5)	red	red	red	red		red	red	red	red	red	red	red

3.4. Summary – Technological developments

3.4.1. Most technological developments have the potential to reduce (as well as increase) distraction, with those reducing visual and biomechanical distraction likely to have the biggest impact

Seventeen technological developments were identified that have the potential to contribute in a positive or negative way to road user distraction. The assessment of their impact indicated that most of the technological developments have the potential to reduce some aspects of distraction.

Technological developments that reduce visual and biomechanical distraction are expected to have the highest impact on road user distraction overall. These are improvements in tactile sensor, dynamic dashboard, head-up display, haptic/tactile feedback technologies.

Developments in data communication technology that provide better connectivity between vehicles and nomadic devices (mobile/smart phones, navigation devices, audio players) can indirectly reduce road user distraction as they have the potential, if properly implemented, to make interaction with nomadic devices much less distracting.

It is expected that future technologies will make more data accessible, give more accurate information, provide better information tailoring, or more effective conveyance of information to the road user. It should be noted that this potential will only be capitalized upon if these technologies are properly implemented. If poorly implemented most technologies also have the potential to increase user distraction.

Some technologies can be combined to cancel out specific drawbacks, or to reinforce a benefit. For example by combining the latest sensor data technology and artificial intelligence it is possible to identify and classify road users in the vicinity of a vehicle and determine the potential collision risk. Night vision and a head-up display can be used to focus the driver’s attention to the most relevant visual cues.

An important topic that surfaced in the assessment is the notion that little is known on the impacts of partial automation of the driving task on road user distraction. Partial automation will allow drivers to focus on safety-related aspects of driving, but may also lead to behavioural adaptation by drivers (i.e. increase road user distraction).

3.4.2. All road user types can benefit from new technological developments to reduce distraction

Although the assessment suggests that all road user types can potentially benefit from the listed technological developments, the potential benefits seem to be the highest for vehicle drivers and occupants and less for cyclists, and pedestrians.

Technological developments that directly limit the need for mechanical interaction between drivers and their vehicle, and that allow for a more efficient presentation of information from the vehicle to the driver, have the highest potential to reduce road user distraction for driver of cars, lorries and motorcycles. These include dynamic dashboards, head-up displays, haptic/tactile feedback, biometry and voice recognition.

Improvements in connectivity between a vehicle and nomadic devices inside the vehicle have the potential to reduce the need for mechanical interaction between drivers and nomadic devices, and thereby also are expected to have a relatively high potential to reduce distraction of vehicle drivers.

Pedestrians, cyclists, children and the elderly are expected to benefit mostly from things that reduce or cancel the need to interact with the nomadic devices they carry (for example haptic/tactile feedback technologies)

4. COUNTERMEASURES TO REDUCE THE ROAD INJURY BURDEN OF DISTRACTION

4.1. Aim

The aim of this chapter is to present the review and assessment of countermeasures which have been used to try and reduce the road injury burden of distraction.

The analysis is based on a review of the literature and consultation with member states and other stakeholders, to examine both policy and technology-based countermeasures. Examples of the former include national rules and standards. Examples of the latter include in-vehicle safety systems and co-operative ITS systems.

The methodology for the reviews of policy countermeasures and technology-based countermeasures is presented in Section 4.2.

The results of the reviews are presented in sections 4.3 (policy) and 4.4 (technology).

A summary of this chapter is presented in Section 4.5.

4.2. Methodology

4.2.1. Policy countermeasures

To examine policy countermeasures, first a research model was developed to enable the description, structuring and analysis of the collected information. Then a stakeholder consultation exercise was undertaken, involving an online questionnaire, telephone and face-to-face interviews, a focus group and a workshop. All collected data were then analysed and summarised. Specific information on the methodology used for these sub-tasks is given in the sub-sections below.

4.2.1.1. Research model and desk research

The research model specifies the theoretical framework for the analysis. It describes what information needs to be collected and how the information is to be structured to enable an efficient analysis.

Through desk research the information was collected and structured using the research model on:

1. National rules, practices and projects in member states, with regard to the availability of tools and actions to reduce distraction risk.
2. Practices and experience from North America (USA, Canada).
3. Existing tools and actions applied in the member states regarding the reduction of distraction risks.
4. Existing studies, standards, initiatives and proposals related to the future needs reduction of risks.
5. Assessment of whether current (policy) standards, standardisation work items in progress and other initiatives are likely to cover the scope needed to meet the objectives.

In total 78 documents were reviewed during the desk research. To arrive at a well-founded assessment of the potential impact of each action and tool, the impact of each was classified using the ordinal scale listed in Table 16 (repeated in Table 22 for ease of reading). As noted in Section 3.2, the classification was carried out by:

- Distraction type – Visual, Auditory, Biomechanical, Cognitive
- Road user type – Drivers in private vehicles, Professional drivers, Motorcyclists, Pedestrians, Cyclists, Children, Elderly

Table 22: Impact classes

Value	Name	Description impact rating scale
3	Strong reduction	Significantly reduces user distraction
2	Moderate reduction	Reduces user distraction
1	Minor reduction	Slightly reduces user distraction
0	Neutral	Has no effect on user distraction
-1	Minor increase	Slightly increases user distraction
-2	Moderate increase	Increases user distraction
-3	Strong increase	Significantly increases user distraction
-	Not applicable	Cannot be used by user group, or applied to influence a specific distraction type

4.2.1.2. Stakeholder consultation

Based on information gathered during the first stage of the study, and on input from the EC and existing contacts of the consortium, relevant stakeholder categories for consultation activities were identified. These categories included:

- Car manufacturers
- Mobility information service providers
- Insurance companies
- National road authorities
- Road safety researchers
- Other relevant interest groups (e.g. road safety organisations)

A list of stakeholders for each category was compiled, along with contact details. The aim was to target stakeholders from different Member States, in particular those countries where there are industry partners active in relevant technological developments.

The final list of stakeholders was used as a master list for all the stakeholder consultation activities, with selections made from this list for each activity according to the requirements. There were four specific methods used to collect data. These were an online questionnaire, interviews, a focus group, and a workshop.

Questionnaire

An online questionnaire was developed using Google Forms. The questionnaire contained 22 questions on the following topics:

- Actions and tools currently being used
- The impact of specific policies on reducing distraction
- The impact of technologies on reducing distraction
- Current research into policies and technologies
- Stakeholder opinions on the most cost-effective policies, technologies and measures to reduce distraction
- Stakeholder opinions on which policies, technologies and measures should be priorities for research and support

Questionnaire completion required approximately 20 minutes. Responses were mostly in 'tick box' format, though there were a number of free-text and Likert-type responses.

The invitation to complete the questionnaire was sent to the 163 stakeholders on the consultation list. Industry organisations on the list were encouraged to share with their members. In addition, a link to the questionnaire was tweeted from the DG MOVE twitter account.

Interview

As well as the online questionnaire, eleven stakeholders were selected and invited to participate in an interview to gather further detailed information and opinion. These stakeholders were geographically disparate, covering UK, France, Belgium, Austria, Ireland, Spain, the Netherlands, Sweden, and pan-European organisations. In addition, all stakeholder groups considered in the questionnaire were included (policy makers, telematics industry, users, car manufacturers and suppliers, research industry and interest groups).

The interviews were flexible with regards to structure, to avoid restricting or over-influencing the interviewees' input. However the discussions aimed to cover:

- The importance of distraction in road safety
- Current measures used in Member States – national practices, procedures, technologies and tools
- The need for additional measures and current barriers to implementation, both at a national and European level
- Current research into distraction and vision for future development

Focus group and workshop

The focus group and the workshop elements provided input (and dissemination) for several tasks as well as more generally for the project.

The focus group was held on 26th February 2015 in Brussels and was intended as an opportunity to disseminate the outputs from the early tasks in the project (notably the review of the size and nature of the problem) and to obtain associated feedback and input from a small number of stakeholders.

The workshop was a full-day meeting with 29 participants at the DG MOVE offices in Brussels, held on 3rd June 2015. The aim of this workshop was to present the preliminary outcomes of the later tasks (notably the reviews of policy countermeasures and the analyses of costs and benefits[4]) and gather input from the stakeholders on these outputs.

The invitation list was defined in cooperation with the Commission and ETSC to ensure representation from a range of stakeholder types and nationalities. There were participants from most stakeholder types (except the insurance industry) and from 11 Member States (Italy, Sweden, Austria, Belgium, Denmark, France, Germany, Hungary, Malta, United Kingdom and the Netherlands).

The workshop involved three discussion sessions. In the morning session the provisional results of the project up until that point were presented to the participants, followed by direct feedback on these results. The remainder of the morning was then taken up with a more general discussion of the project, the results and the topic of reducing road user distraction. In the afternoon, the two sessions were more structured and interactive discussions which used the technique of a 'serious game' to obtain input for deployment scenarios of selected interventions. This was chosen as a method since it was crucial that all stakeholders engaged with discussions and provided meaningful and targeted feedback. The 'game' used focused on stakeholder roles and challenged participants to express their expectations towards other stakeholders, and to share their insights and interests with each other and with the project team. As there were no representatives of insurance companies present, TRL acted in lieu of them.

In the first afternoon session, participants were asked to focus on the deployment of in-vehicle distraction warning systems, identifying the needs and expectation between stakeholders. Each stakeholder group was represented by a flip-chart. Needs, wants and expectations of stakeholder groups were written on post-its and stuck onto the flip-chart of other stakeholders. The colour of the post-it identified the requesting stakeholder group. Each stakeholder group was then asked to respond to the most interesting or challenging requests of the other stakeholders.

In the second session, participants were asked to suggest practical actions that the EC should undertake from the perspective of their stakeholder group. Each stakeholder group then presented these to the EC and the rest of the group and each was discussed from various perspectives.

The findings from the focus group and workshops are not reported in a separate chapter in this report. Rather, they are reported within the other results chapters and within the final conclusions and recommendations, as appropriate.

4.2.1.3. Analysis and Reporting

During the study the methodology for the analysis of the collected information was improved. It was originally the intention of the project team to use cluster analysis to analyse the collected data. Cluster analysis is a good technique to recognise patterns in

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[4] Due to this, some of the workshop outputs feed into the next chapter on costs and benefits.

large sets of structured data. The questionnaire produced structured data that could be used for a cluster analysis, but the first phase of the study showed that the most relevant sources of information are those that produce unstructured data (literature, workshops and interviews). In consultation with the EC it was therefore decided to opt for a review of the all information by ITS experts rather than a cluster analysis.

4.2.2. Technology-based countermeasures

Different types of technical systems were (mostly qualitatively) rated according to their potential effect to mitigate or reduce the most problematic types of distraction. This was done based on the following information sources:

1. The review of distraction and technological developments discussed in Section 2
2. Corporate press releases and presentations on available types of safety systems or soon-to-be-available systems
3. Consultation of in-house experts of the involved partners.

Within each category or type of system, specific systems that are on the market or well documented were described and evaluated. Depending on available literature, the effectiveness of systems in alleviating distraction were defined, on either a quantitative or a qualitative level. All systems and types were at least rated according to their relative potential to alleviate distraction now and in the near future.

The following specific procedure was followed:

1. Overview and description of existing systems, by road-user category, and by mechanism of effect (for example prevention, mitigation) based on:
   - existing knowledge, literature, press releases
   - expert knowledge
2. Ratings of the effect of systems on driving behaviour, distraction, attention, based on published evidence where possible, or otherwise based on expert opinions combined with a theoretical appraisal of the mechanism by which the system is designed to have an effect.

4.3. Results – policy countermeasures

4.3.1. Research model and desk research

Based on the desk research a list of 26 actions and eight tools[5] that can be used to reduce road user distraction were identified and described (Table 23).

[5] Actions in this context are things that can be done, and tools are the policy-instruments which can be used to do them.

Table 23: Overview of Actions and Tools.

No	Name	Description	Action / Tool
1	Raise awareness through public awareness campaigns	e.g. On dangers of distractions in general, making phone calls in traffic, etc.	Action
2	Raise awareness by mandating warnings in advertisements	e.g. Mandating device manufacturers to warn for distraction in their advertisements	Action
3	Raise awareness in driver license programmes	Teach incumbent drivers about the dangers of distraction and mitigation measures	Action
4	Educational campaigns in schools	Raise awareness of children and youngsters on distraction in traffic through educational programmes in primary and secondary schools	Action
5	Promote use of specific products	Products raising alertness of road user, e.g. Drowsiness warning, lane guidance systems through fiscal discounts or discounted insurance fees	Action
6	Mandate use of specific products	Products raising alertness of road user, e.g. Drowsiness warning, lane guidance systems through fiscal discounts or discounted insurance fees	Action
7	Promote specific use under certain conditions	e.g. Financial reward or insurance discount for not making phone calls while driving or riding a bicycle based on voluntary monitoring	Action
8	Discourage specific use under certain conditions	e.g. Handsfree calling while driving, rightside headphone use only while cycling or walking in traffic	Action
9	Ban specific use under certain conditions	e.g. Handsfree calling while driving, rightside headphone use only while cycling or walking in traffic	Action
10	Promote proper installation of nomadic devices	e.g. Through standardisation of the interface for mounting, power and data between dashboard and device	Action
11	Regulate installation requirements nomadic devices	e.g. Mandatory use of mounting solutions for nomadic devices, TV screens only visible to passengers	Action
12	Promote development of specific technology or products	Promote development of new technology and products preventing or mitigating distraction of road users	Action
13	Promote safe product design	e.g. Recommend mobile phones to block incoming calls above certain speeds, audio players to lower volume when nearing a crossroads, etc.	Action
14	Mandate safe product design	e.g. Mandate mobile phones to block incoming calls above certain speeds, audio players to lower volume when nearing a crossroads, etc. through certification	Action
15	Discourage use of specific products	e.g. In-vehicle TV units, in-dash touch screens, etc	Action
16	Ban use of specific products	e.g. In-vehicle TV units, in-dash touch screens, etc	Action

No	Name	Description	Action / Tool
17	Discourage sale of specific products	e.g. In-vehicle TV units, in-dash touch screens, etc	Action
18	Ban sale of specific products	e.g. In-vehicle TV units, in-dash touch screens, etc	Action
19	Promote deployment of roadside / central systems	e.g. Systems supporting lane guidance, erratic driving detection systems	Action
20	Mandate deployment of roadside / central systems	e.g. Systems supporting lane guidance, erratic driving detection systems	Action
21	Promote safe road infrastructure	e.g. By providing best practices to prevent or mitigate distraction, promote research into road design with less distraction	Action
22	Mandate safe road infrastructure	e.g. By mandating rumble strips	Action
23	Discourage distraction sources off the road	Recommending where billboards are best placed to limit undesirable distraction of road users, and how ads should be displayed (contents, form)	Action
24	Ban and regulate distraction sources off the road	Legislation to ban billboards on network locations with a high driver workload, ban distracting content and display forms.	Action
25	Enforcement	Enforcing of bans, conditional use requirements, etc.	Action
26	Promote understanding of distraction	e.g. By promoting research, development of knowledge and data bases, etc.	Action
27	Legislation	e.g. Banning mobile phone use in vehicles	Tool
28	Publicity campaigns	e.g. To raise awareness of the dangers of distraction in traffic	Tool
29	Financial support	e.g. For R&D, road infrastructure changes, promoting sale or use of specific products, insurance discounts, promote safe driving incentives, etc.	Tool
30	Certification	Amend or establish certification schemes to prevent distracting devices of entering the market, and promote product design limiting distraction, to harmonise driver training on distraction	Tool
31	Standardisation	e.g. To establish common methods to measure work load, harmonise design of common HMI components (e.g. Iconography in SatNavs, dashboards, etc.)	Tool
32	Recommendations	e.g. Recommending road authorities, service providers, advertising companies certain distraction mitigating measures	Tool
33	Best practices	e.g. For road infrastructure design, the use of billboard along roads	Tool
34	Agreements	e.g. with mobile phone manufacturers on product design, driver workload with car manufacturers, insurance terms with insurance companies	Tool

Reference documents were mapped to the actions and tools (Appendix D) and served as the basis for an expert assessment on the impact of the actions and tools on the different types of distraction (Table 24) and different road user types (Table 25). The assessment suggests relatively high impacts from actions concerning safer product design, better integration between nomadic devices and vehicles and the banning of products that are inherently distracting (e.g. in/on-dashboard video players). It also suggests legislation and certification are the most effective tools.

Table 24: Classification of impact of actions and tools per distraction type.

No	Name	Visual	Auditory	Biomechanical	Cognitive
1	Raise awareness through public awareness campaigns	1	1	1	1
2	Raise awareness by mandating warnings in advertisements	1	1	1	1
3	Raise awareness in driver license programmes	1	1	1	1
4	Educational campaigns in schools	1	1	1	1
5	Promote use of specific products	0	0	0	1
6	Mandate use of specific products	-1	-1	-1	1
7	Promote specific use under certain conditions	1	1	1	-1
8	Discourage specific use under certain conditions	1	1	1	-1
9	Ban specific use under certain conditions	2	2	2	-2
10	Promote proper installation of nomadic devices	2	2	2	0
11	Regulate installation requirements nomadic devices	2	2	2	0
12	Promote development of specific technology or products	1	1	1	1
13	Promote safe product design	1	1	1	1
14	Mandate safe product design	3	3	3	3
15	Discourage use of specific products	1	1	1	1
16	Ban use of specific products	2	2	2	2
17	Discourage sale of specific products	1	1	1	1
18	Ban sale of specific products	2	2	2	2

No	Name	Visual	Auditory	Biomechanical	Cognitive
19	Promote deployment of roadside / central systems	-1	0	0	1
20	Mandate deployment of roadside / central systems	-1	0	0	2
21	Promote safe road infrastructure	0	0	1	1
22	Mandate safe road infrastructure	0	0	1	1
23	Discourage distraction sources off the road	1	0	0	1
24	Ban and regulate distraction sources off the road	2	0	0	2
25	Enforcement	1	1	1	1
26	Promote understanding of distraction	1	1	1	1
27	Legislation	3	3	3	3
28	Publicity campaigns	1	1	1	1
29	Financial support	1	1	1	1
30	Certification	2	2	2	2
31	Standardisation	1	1	1	1
32	Recommendations	1	1	1	1
33	Best practices	1	1	1	1
34	Agreements	1	1	1	1

Table 25: Classification of impact of actions and tools per distraction type

No	Name	Drivers private vehicles	Professional driver	Motorcyclists	Pedestrians	Cyclists	Children	Elderly
1	Raise awareness through public awareness campaigns	1	1	1	1	1	1	1
2	Raise awareness by mandating warnings in advertisements	1	1	1	1	1		1
3	Raise awareness in driver license programmes	1	1	1				
4	Educational campaigns in schools				1	1	1	
5	Promote use of specific products	0	0	0				
6	Mandate use of specific products	0	0	0				
7	Promote specific use under certain conditions	1	1	1	2	2		0
8	Discourage specific use under certain conditions	1	1	1	2	2	0	0
9	Ban specific use under certain conditions	2	2	2	3	3	0	0
10	Promote proper installation of nomadic devices	1	1	0		0		
11	Regulate installation requirements nomadic devices	1	1	0		1		
12	Promote development of specific technology or products	1	1	1	1	1	1	1
13	Promote safe product design	1	1	1	1	1	1	1
14	Mandate safe product design	3	3	3	3	3	3	3
15	Discourage use of specific products	1	1	1	1	1	1	1
16	Ban use of specific products	2	2	2	2	2	2	2
17	Discourage sale of specific products	1	1	1	1	1	1	1
18	Ban sale of specific products	2	2	2	2	2	2	2
19	Promote deployment of roadside / central systems	0	0	0				
20	Mandate deployment of roadside / central systems	0	0	0				
21	Promote safe road infrastructure	1	1	1	1	1	1	1

No	Name	Drivers private vehicles	Professional driver	Motorcyclists	Pedestrians	Cyclists	Children	Elderly
22	Mandate safe road infrastructure	1	1	1	1	1	1	1
23	Discourage distraction sources off the road	1	1	1				
24	Ban and regulate distraction sources off the road	2	2	2				
25	Enforcement	1	1	1	1	1	1	1
26	Promote understanding of distraction	1	1	1	1	1	1	1
27	Legislation	3	3	3	3	3	3	3
28	Publicity campaigns	1	1	1	1	1	1	1
29	Financial support	1	1	1	1	1	1	1
30	Certification	2	2	2	2	2	2	2
31	Standardisation	1	1	1	1	1	1	1
32	Recommendations	1	1	1	1	1	1	1
33	Best practices	1	1	1	1	1	1	1
34	Agreements	1	1	1	1	1	1	1

4.3.2. Questionnaire results

4.3.2.1. Sample characteristics

A total of 35 participants completed the online questionnaire. Fourteen Member States were represented in the final sample. There was a good mix of small and large countries, as well as a wide geographical spread. In total, 57% (n=20) of the sample consisted of participants from Belgium, Italy, France, Germany, Sweden and the United Kingdom (Figure 14). The category 'other' included Greece, Australia and Norway. There was only one regional/ local authority, and three organisations described their remit as 'regional, provincial, county, district'. Otherwise here was a good mix of organisations with international, European and National areas of work (Figure 15).

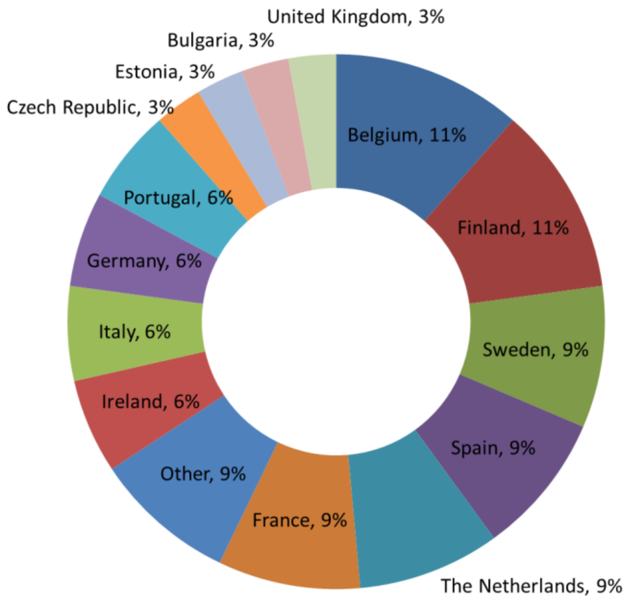

Figure 14: Spread of countries in which the organisations are established (Question 3)

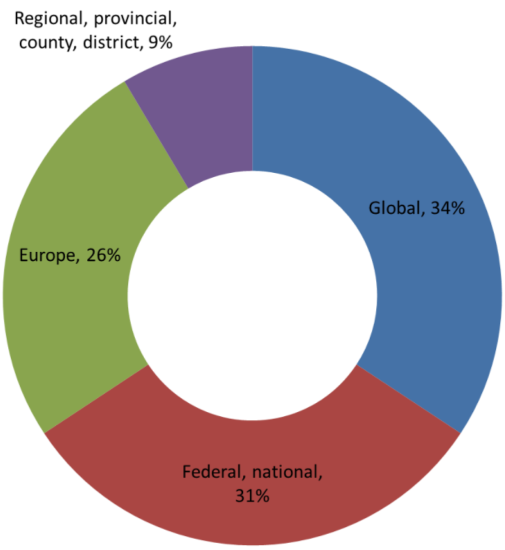

Figure 15: Geographical work area of the organisations (Question 4)

Half of the respondents were from road safety organisations (27%) and automotive manufacturers/ industry suppliers (23%), with the remainder from a good range of other organisation types (Figure 16).

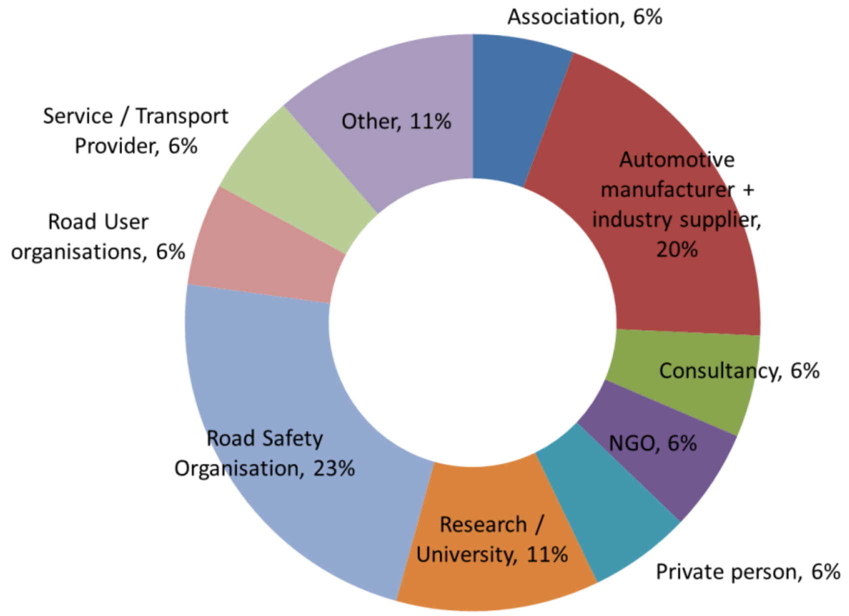

Figure 16: Main role of the organisations/respondents (Question 5)

The category 'other' is made up of one respondent from each of the following: European (umbrella) organisation, Parliament (national)/ ministry, regional/ local authority, and road administration. None of the organisations surveyed reported fulfilling roles within driver training, public enterprise, the police, or emergency services. Participants were asked to further classify their organisation with relation to the types of activities undertaken. This resulted in splitting the sample into six categories of organisation (Figure 17).

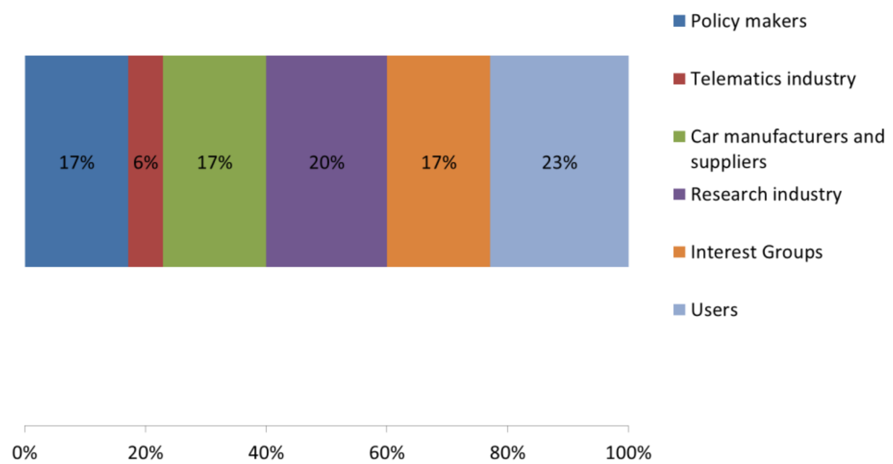

Figure 17: Organisation 'categories' selected by respondents (Question 6)

Although the data in Figure 14 to Figure 17 suggest a reasonable range of stakeholder types, it should be noted that this is not a representative sample of the entire stakeholder population. Results should therefore be interpreted with caution, particularly for those questions answered only by a specific stakeholder category. Furthermore, the 'categories' selected by participants in question 6 (Figure 17) served as a questionnaire filter. Participants were asked a number of questions specific to the category they selected. The responses to these questions are detailed in the sections below.

4.3.2.2. Policy makers

Participants who classified their organisation's role as 'policy makers' were asked about their involvement with a number of policy measures as well as the perceived impact of these measures. A total of six organisations were included in this subsample.

Table 26 and Table 27 detail the list of thirty policies about which participants were asked, as well as the number of organisations (from the six) that reported having involvement in these areas.

Table 26: Policy measures most likely to be addressed by the policy makers surveyed[6] (Question 7)

Policy measures	Level of involvement by organisations surveyed (n=6)
Distraction in driver license **Enforcement of behaviour** **Legislation of usage conditions** **Limit visual distraction beside the road** **Public Awareness campaigns** **Road users recommendations/best practices**	100%
Promote deployment detection/warning technology/products **Promote development mitigating technology/products** **Promote installation of devices/equipment** **Support/promote research**	83%
Financial support (of deployment) **Mandatory installation of devices** **Mandatory usage requirements** **Promote development detection/warning technology/products**	67%

Table 27: Policy measures least likely to be addressed by the policy makers surveyed (Question 7)

[6] Note that only respondents who categorised their organisations as 'policy makers' were asked questions 7 and 8. Hence, these results are based on n=6 respondents.

Policy measures	Level of involvement by organisations surveyed (n=6)
Banning use/sale devices/equipment	50%
Mandatory deployment roadside/central systems	
MoU with SPs, car manufacturers	
Promote deployment mitigating technology/products	
Insurance incentives	33%
Mandatory deployment detection/warning technology/products	
Mandatory deployment mitigating technology/products	
Mandatory messages in communication	
Mandatory mounting requirements nomadic devices	
Promote less distracting product design	
Usage restrictions passengers	
Headphone bans	17%
Develop workload metrics	0%
Mandate less distracting product design	
Reward good behaviour	

Table 26 shows the policies with which policy makers were most likely to report involvement. Each box in the shaded/non-shaded bar represents one of the respondents. As expected, the areas on which policy makers were most likely to be focused related to measures such as legislation of usage, public awareness campaigns and enforcement. However, other areas such as promoting the development and deployment of technologies, and mandating the installation and use of devices, were also covered by at least four of the six respondents.

Table 27 shows the policy measures with which organisations were less likely to report involvement. None of the organisations interviewed addressed issues relating to headphone bans or rewarding good behaviour (both areas that could be within their remit if desired). Although 'development of workload metrics' and 'mandating product design' were not also not reported by any of the participants, this could be due to the fact that these are not necessarily areas in which policy makers would be expected to engage. The development of workload metrics, in particular, is more likely to be a priority for research organisations.

Figure 18 shows that although the organisations surveyed were involved with at least 10 of the 30 measures about which they were asked, there was considerable variability in involvement.

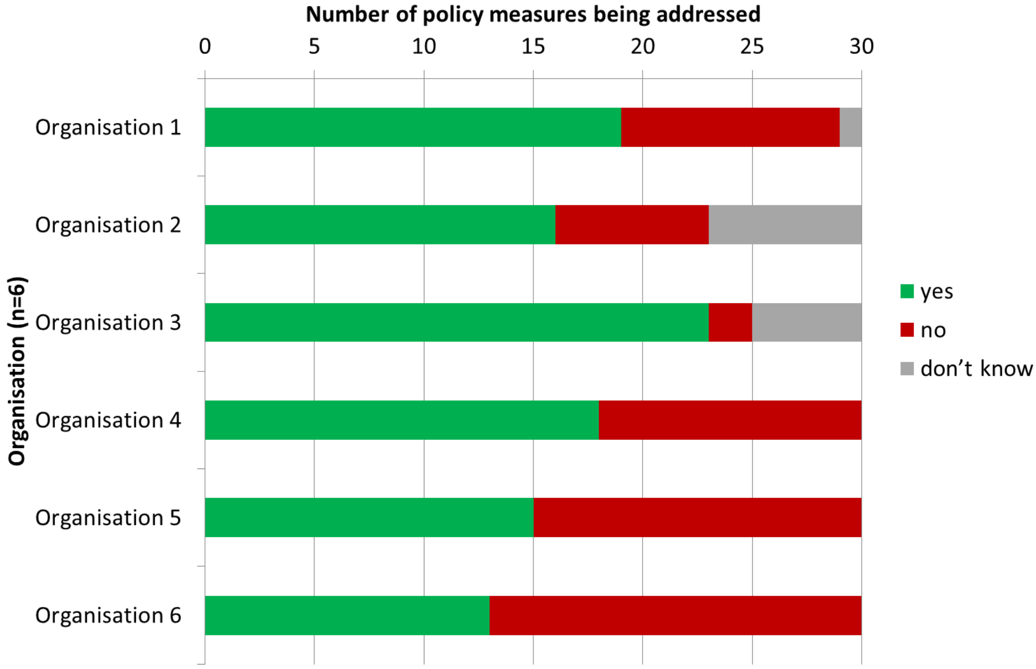

Figure 18: Number of policies being addressed, by policy making organisation surveyed

Policy making organisations were also asked about the impact that policy measures had been found to have on distraction. The question specifically referred to policy measures that had been evaluated (Figure 19).

Figure 19 shows those measures that policy makers believed to have shown most promise; in other words those that were rated unanimously as likely to have a positive impact (i.e. to reduce distraction[7]). It is important to note that little is known about the quality of research on which these answers are based, and the robustness of the methods used to assess the impact of such measures by respondents.

[7] Note that only two measures were rated by policy makers as having a negative impact (i.e. to increase distraction), and these were only rated by a single participant in both cases.

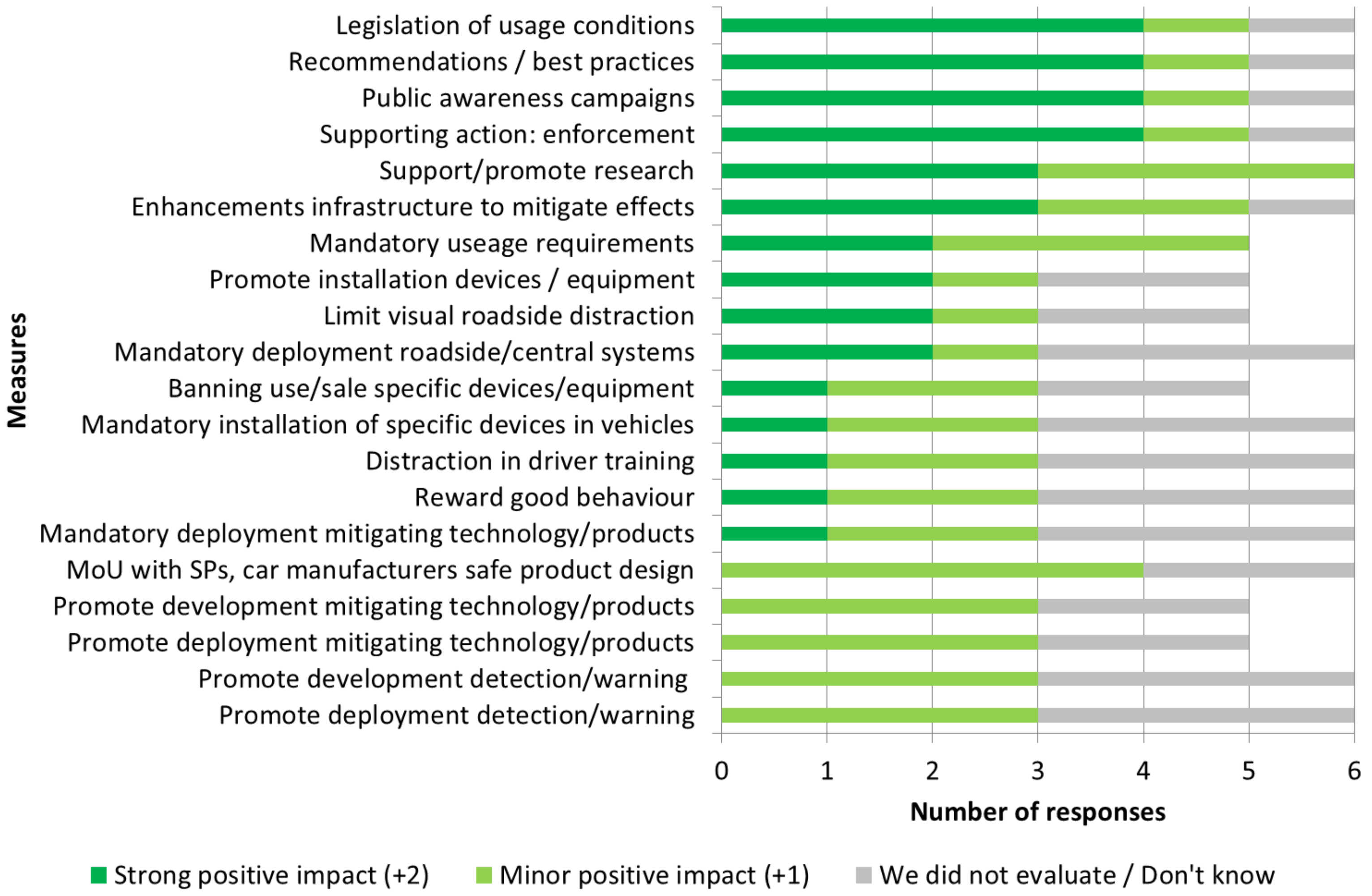

Figure 19: Estimated positive impact (i.e. reducing distraction) of policy measures on distractions – policy makers (Question 8)

4.3.2.3. Telematics/ automotive companies

The subsample of organisations classifying their main activity as telematics or automotive companies comprised eight respondents. They were asked about their level of research involvement with seventeen different technologies. Table 28 and Figure 20 show their responses to this question.

Table 28: Telematics/auto manufacturer[8] involvement in research into the impact of technologies on reducing road user distraction (Question 9)

Technologies	Research involvement by organisations surveyed (n=8)
Sensor data	63%
Haptic / tactile feedback **Increased vehicle connectivity** **Intra-nomadic-vehicle connectivity** **Biometry** **Voice recognition systems** **Conditional automation (SAE=3)**	50%
Tactile sensor technology **Head-up display** **Extra-nomadic-vehicle connectivity** **Artificial intelligence** **High automation (SAE=4)** **Full automation (SAE=5)**	38%
Non-flat display technologies **Night vision** **Virtual reality**	25%
Dynamic dashboard	13%

The most frequently reported area of research involved sensor data, with five of the eight respondents reporting being involved in this. Other technologies received variable levels of attention. It should be noted that many of these are highly advanced

[8] Note that only respondents who categorised their organisations as 'Telematics / automotive' companies were asked questions 9 and 10. Hence, these results are based on n=8 respondents.

technologies, and as such they may not currently be the focus of these types of organisations.

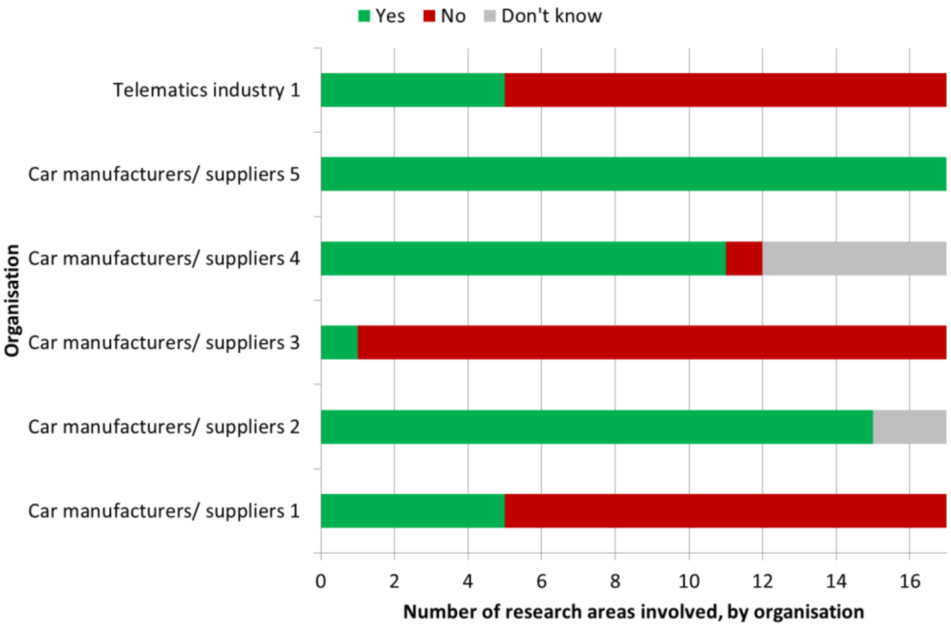

Figure 20: Organisations involved in the seventeen areas of research listed in the questionnaire

A more detailed look at the responses by organisation (Figure 20) shows the responses to question 9 are skewed by three organisations who have reported being involved in the majority of the areas of research listed. Two organisations surveyed (one in the telematics industry and another in the 'car manufacturers and suppliers' category) reported not being involved in any of the above areas of research and as such are not included in the figure.

Respondents from the automotive/ telematics organisations were also asked to rate the likely effect of the different technologies. Figure 21 displays the technologies participants were most likely to believe reduced distraction (technologies that received no 'negative impact' ratings). Telematics and automotive industry participants believe voice recognition to be the most effective technology to reduce distraction. Biometry, head-up displays, and artificial intelligence are also expected to have a positive impact (i.e. to reduce distraction) by the majority of telematics/automotive companies.

Some of the technologies were rated as less well-understood by telematics and auto manufacturers (Figure 22), or as having some negative effects on distraction. These are most often the most advanced technologies (such as high levels of automation).

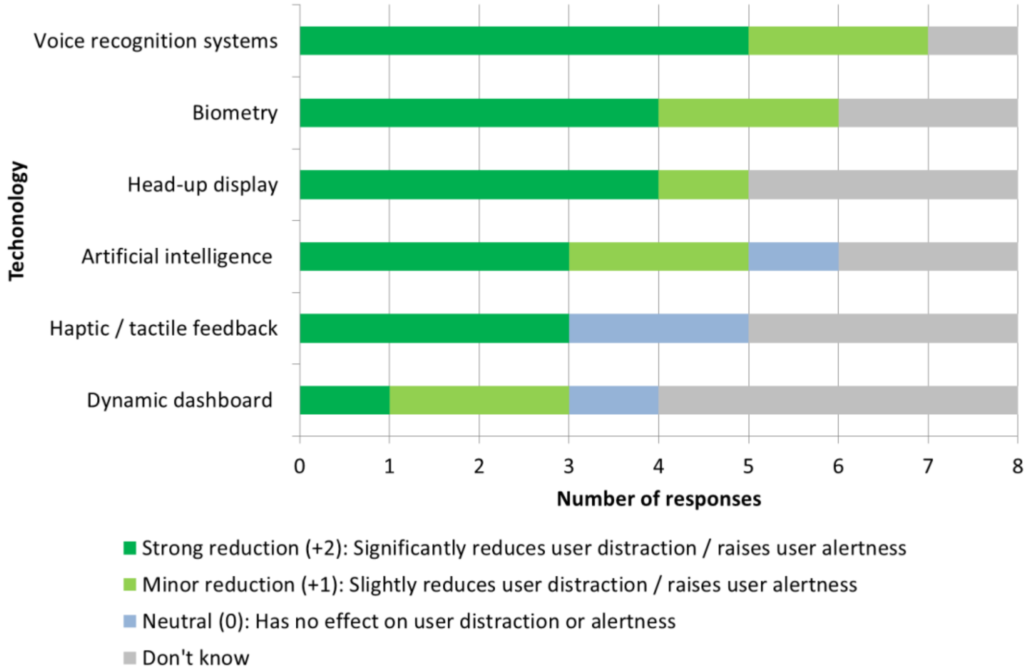

Figure 21: Estimated positive impact of policy measures on distractions – telematics/ auto manufacturers (Question 10)

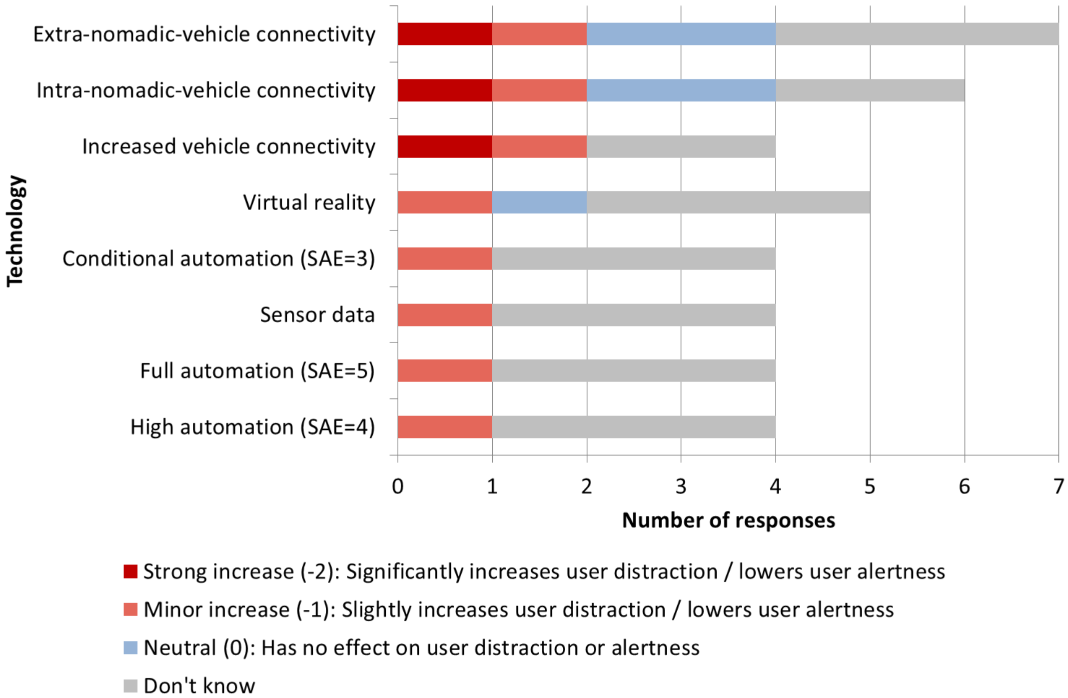

Figure 22: Technologies believed to increase distraction or those technologies less well-researched – telematics/ auto manufacturers (Question 10)

4.3.2.4. Research institutes

Seven organisations were classified as 'research institutes', and were asked about areas of research being undertaken as well as areas that showed future promise (Figure 23).

Research institutes overall rate 'head-up display' and 'biometry' as being likely to be the most cost-effective technologies to reduce distraction.

Respondents were also asked to rate the anticipated impact of these technologies (based on their own knowledge and research) in reducing distraction (Figure 24). Interestingly, head-up display technologies were generally rated as having little or equivocal evidence to support their effectiveness, meaning that the finding regarding the potential cost-effectiveness of this technology (Figure 23) needs to be treated with caution.

Figure 24 also shows that as was the case for automotive and telematics organisations, biometry is one of the areas perceived as having a strong potential to reduce distraction by research institutes. Research institutes also seem to have more positive views regarding the effects on distraction of technologies such as artificial intelligence and high levels of automation, and different opinions on the potential of voice recognition systems, relative to that held by automotive/ telematics organisations, tending to believe them to be an 'unknown' or likely to have a neutral or negative impact (i.e. to increase distraction).

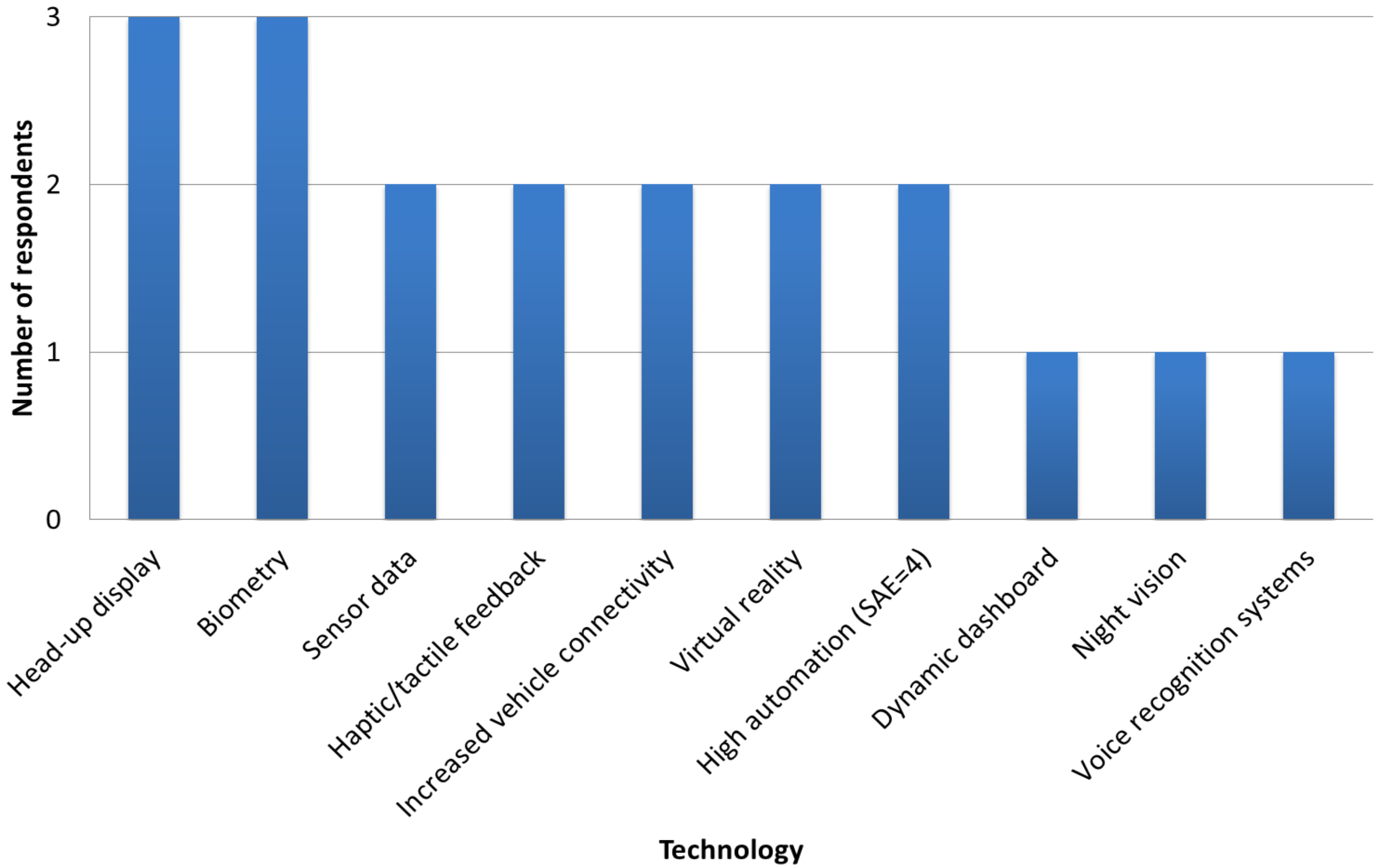

Figure 23: Technologies respondents[9] from research institutes believed would be most cost-effective in reducing distraction in the next 5 years (Question 11)

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[9] Note that only respondents who categorised their organisations as 'Research institutes' companies were asked questions 11 and 12. Hence, these results are based on n=7 respondents.

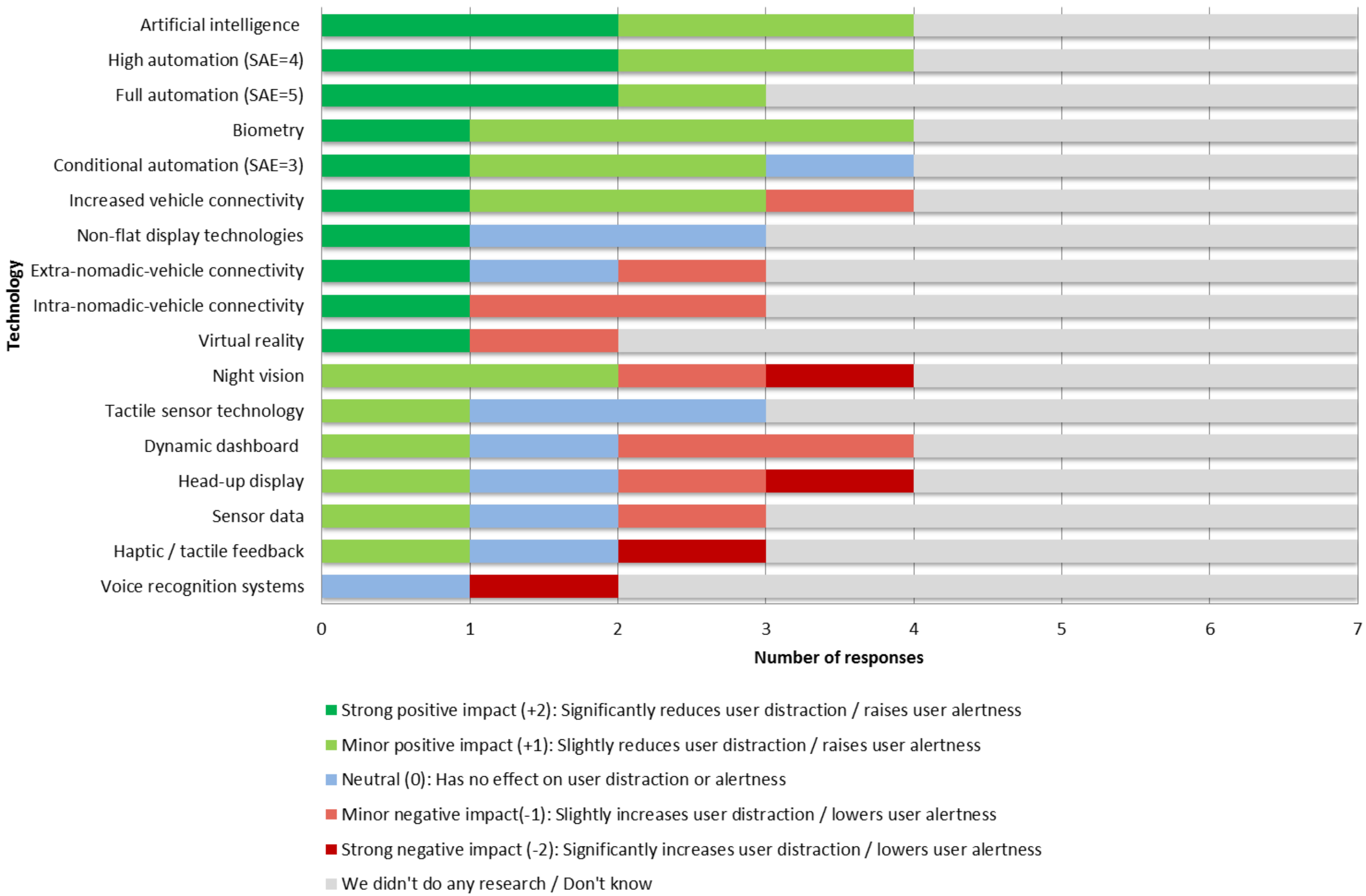

Figure 24: Perceived impact of technologies on distraction from research institutes (Question 12)

These differences may stem from the different assumptions these types of organisations have on the nature of driving. For example it is possible that respondents from telematics and automotive organisations assume that voice recognition will reduce distraction in tasks that drivers want to carry out anyway (calling, texting, email) whilst researchers assume it will lead to additional distraction and an encouragement of drivers in undertaking these activities more.

All listed technologies are being researched by at least one institute. However, two of the seven research organisations surveyed had not undertaken research in any of the areas. Another of the organisations reported only researching one of the areas.

Respondents from research institutes were also asked to judge which policies were most likely to be cost effective in the short to medium term future (Figure 25).

Public awareness campaigns were rated well by research institutes and were perceived by some of the respondents to have a positive impact by reducing distraction (Figure 26). Other measures such as distraction in driver training, insurance incentives and headphone bans were mentioned, though no option was selected by more than three respondents. Many areas had not been researched (Figure 27).

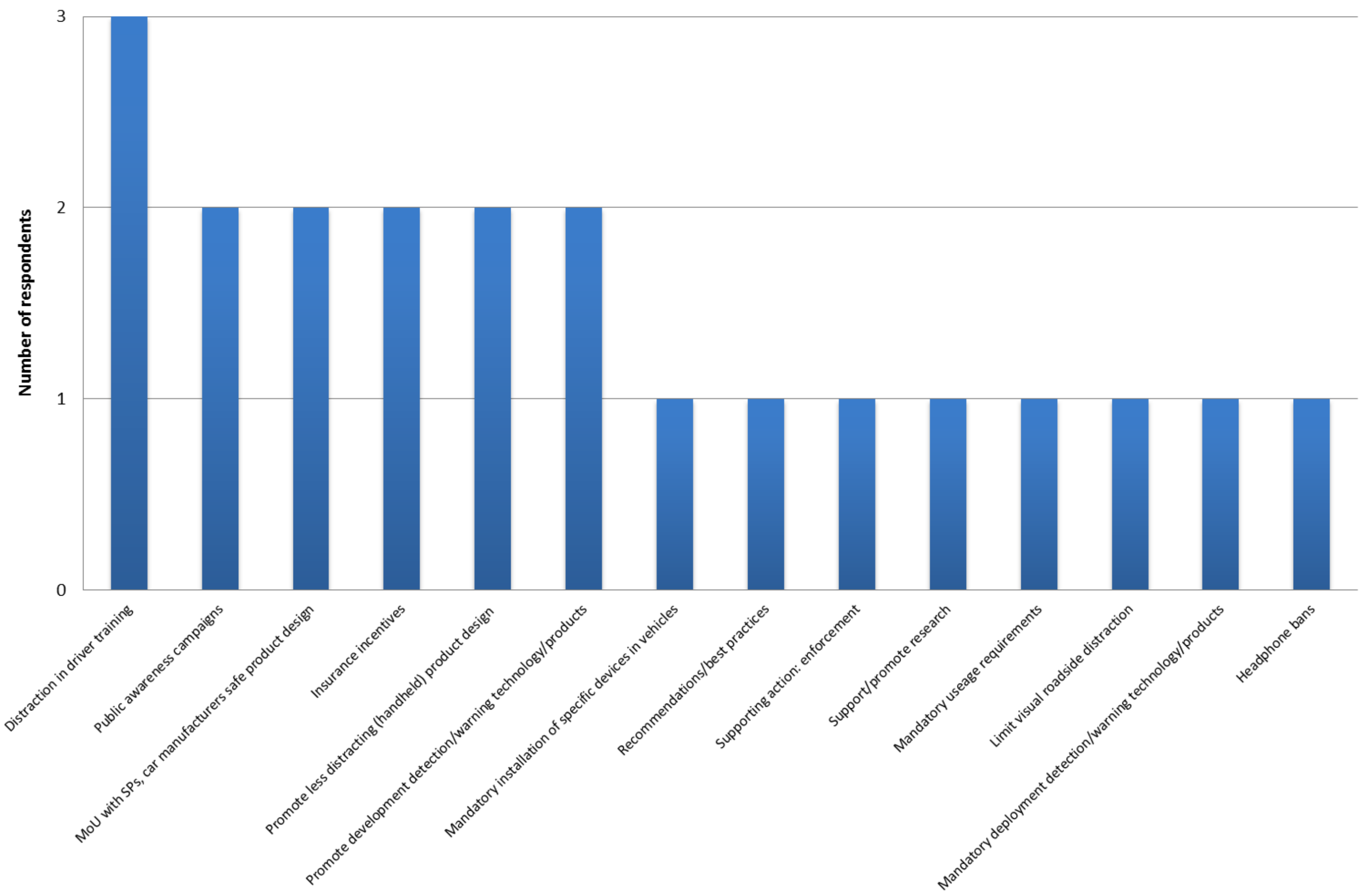

Figure 25: Policies respondents from research institutes believed would be most cost-effective in reducing distraction in the next 5 years (Question 13)

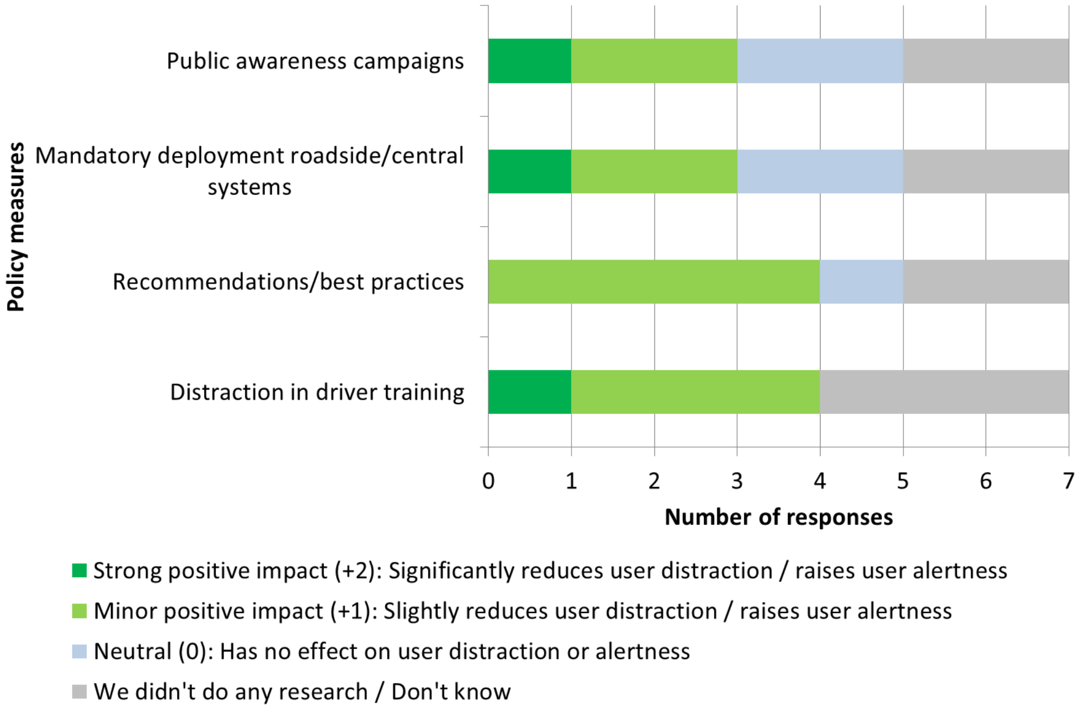

Figure 26: Policies believed to have a positive impact on distraction – research institutes (Question 14)

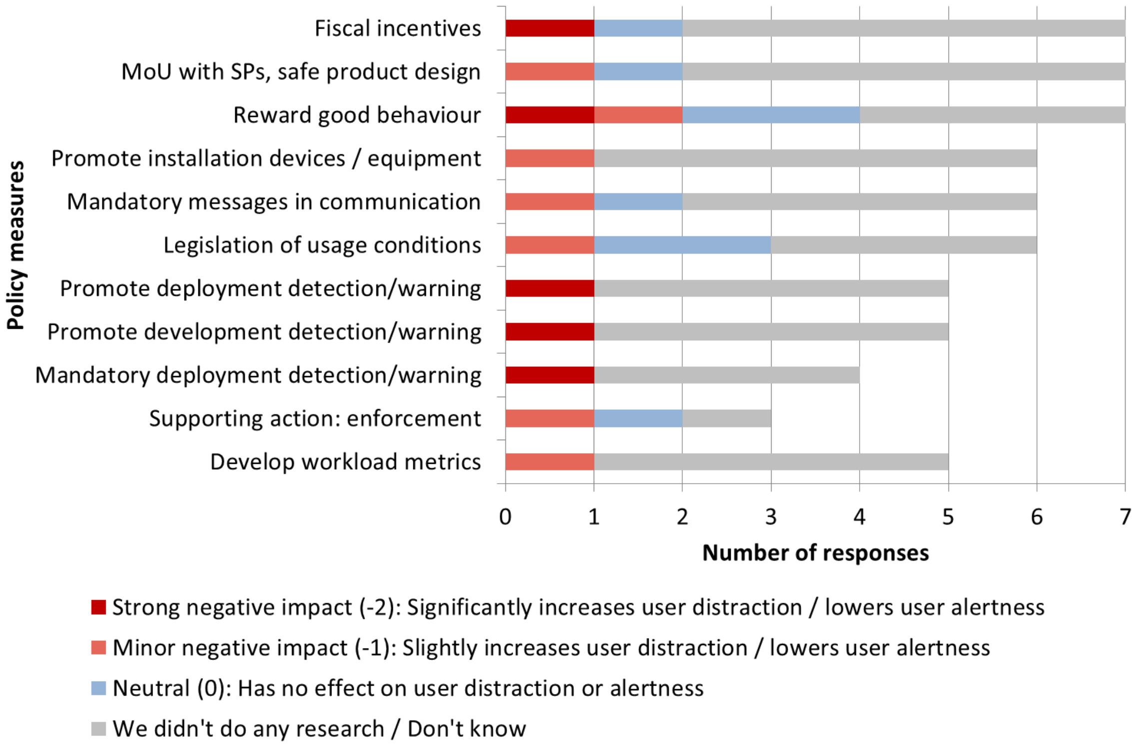

Figure 27: Policies believed to have a negative impact on distraction – research institutes (Question 14)

4.3.2.5. Interest groups and users

Fourteen respondents were classified as either 'interest groups' or 'users'. Of the organisations surveyed[10], very few were carrying out research in the impact of technologies on road user distraction (Table 29).

Table 29: Technologies being researched by 'interest groups' and 'users' (Question 15)

Technology	Number of organisations undertaking research
Virtual reality	2
Sensor data	1
Non-flat display technologies	1
Night vision	1
Artificial intelligence	1

Respondents in these categories were asked to rate their perceptions of the likely impact of policy and technology measures in reducing distraction (Figure 28 and Figure 29 respectively).

Not many of these had been researched by the organisations surveyed and 'don't know' was a very common response. None of the policy measures listed was perceived as being likely to increase distraction. When rating the impact of technologies, some were perceived as increasing distraction, but again the dominant response was 'don't know'.

[10] Note that only respondents who categorised their organisations as 'Interest groups' and 'users' responded to questions 15 and 16. Results are based on n=14 respondents.

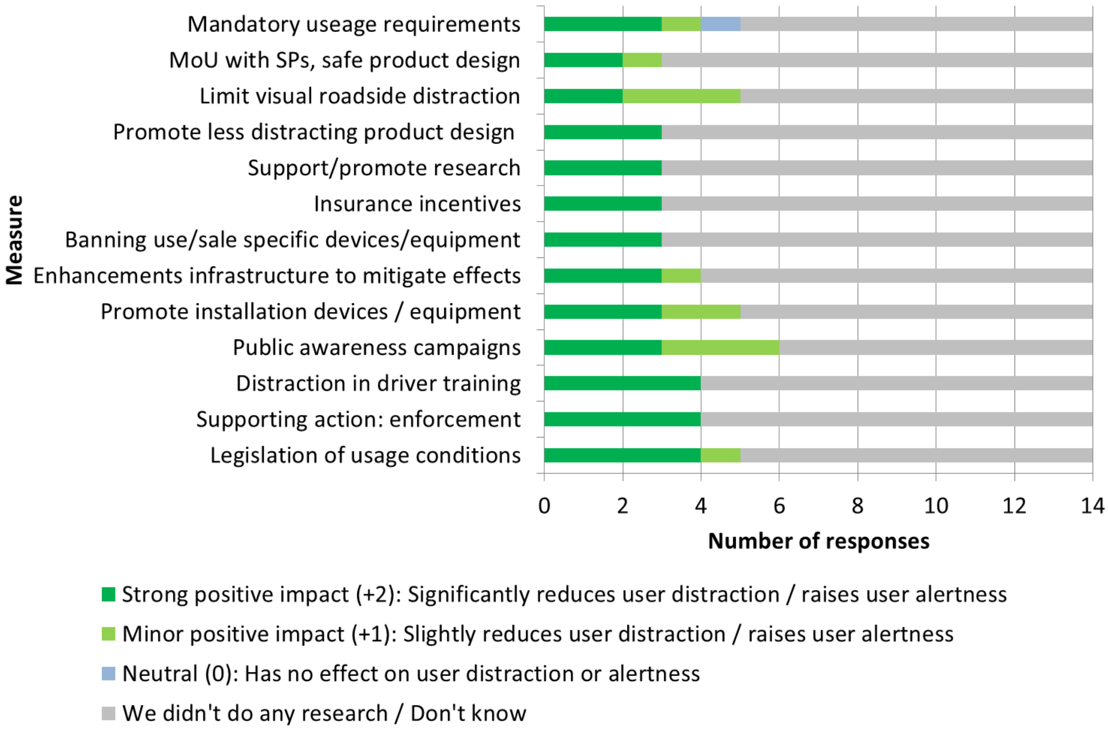

Figure 28: Policies believed to reduce or increase dangerous distractions by interest groups and users (Question 16)

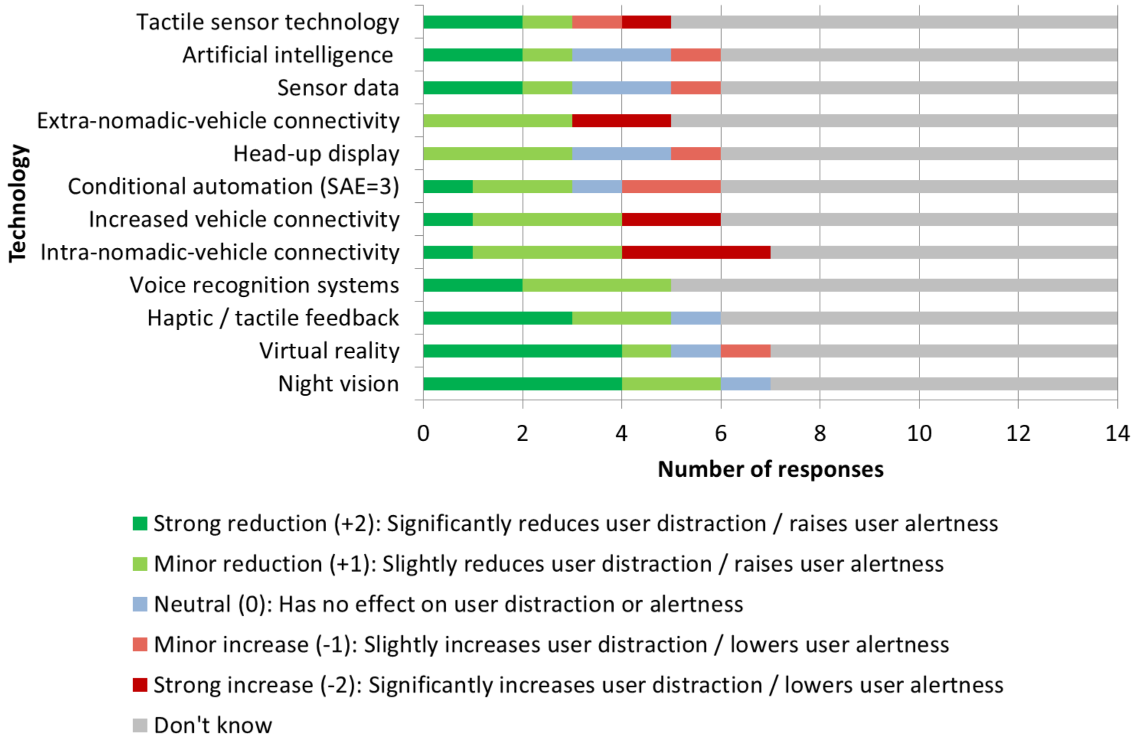

Figure 29: Technologies believed to reduce or increase dangerous distractions by interest groups and users

4.3.2.6. All respondents

The following questions were asked to all 35 respondents who completed the questionnaire.

Question 18 asked all respondents which three technologies should be considered as priorities for further research. The three perceived as priorities were voice recognition systems, night vision and biometry. Figure 30 shows these data.

Question 19 asked all respondents which policy measures should be considered priorities for further research relating to distraction. Legislation of usage conditions, and public information campaigns were voted as the top priorities. Table 30 shows these data.

Questions 20 and 21 asked respondents who they thought should take a lead in setting the research agenda with respect to technologies and policies. The data from these questions are shown in Figure 31 and Figure 32. As expected, respondents believed that the automotive/ car manufacturing industry should play a lead role in setting the research agenda for technologies to reduce distraction. Conversely, when asked about who should play the major role in setting the agenda relating to policy measures, participants believed that this should lie mostly with the EC and National governments.

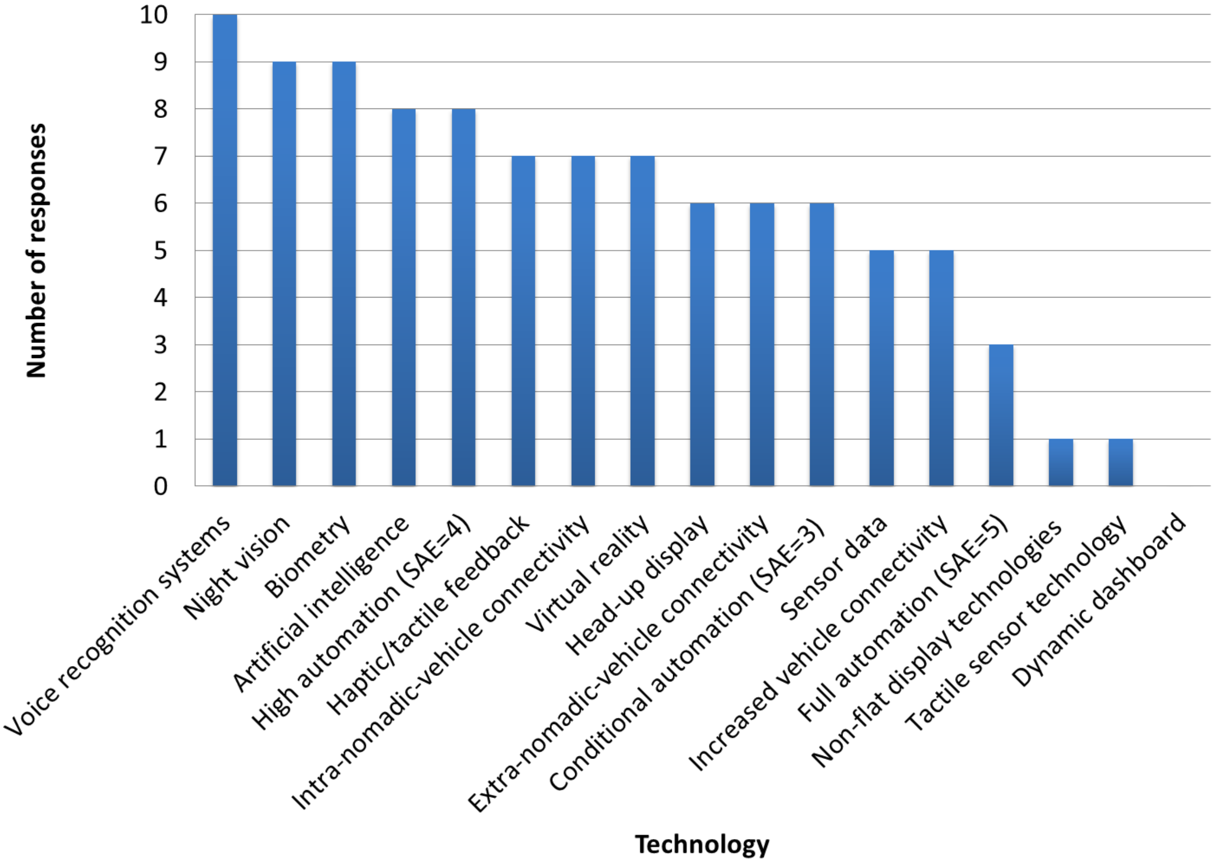

Figure 30: Technologies respondents believed should be considered priorities for further research / support with respect to decreasing distraction (Question 18)

Table 30: Policy measures that should be considered priorities for further research (Question 19)

Policy measure	Number of participants who selected this option
Legislation of usage conditions	11
Public awareness campaigns	9
Support / promote research	6
Increase attention to distraction in driver license programmes	6
Mandatory installation of specific devices in vehicles	5
Recommendations / best practices	5
Supporting action: enforcement	5
Limit visual distraction beside the road, e.g. Limit number of billboards, regulate size, distance to road, form and content of messages.	5
Banning use or sale of specific devices / equipment	4
Promote installation of devices/equipment, e.g. through EuroNCAP	4
Enhancements to infrastructure to mitigate the effects of distraction, e.g. Rumble strips	4
Promote deployment of distraction detection and warning technology and products	4

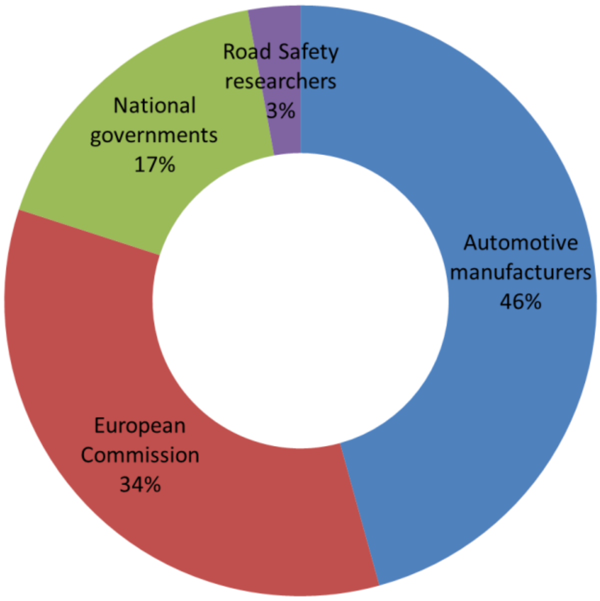

Figure 31: Based on the knowledge of your company, who has the major role in setting the research agenda with respect to technologies? (Question 20)

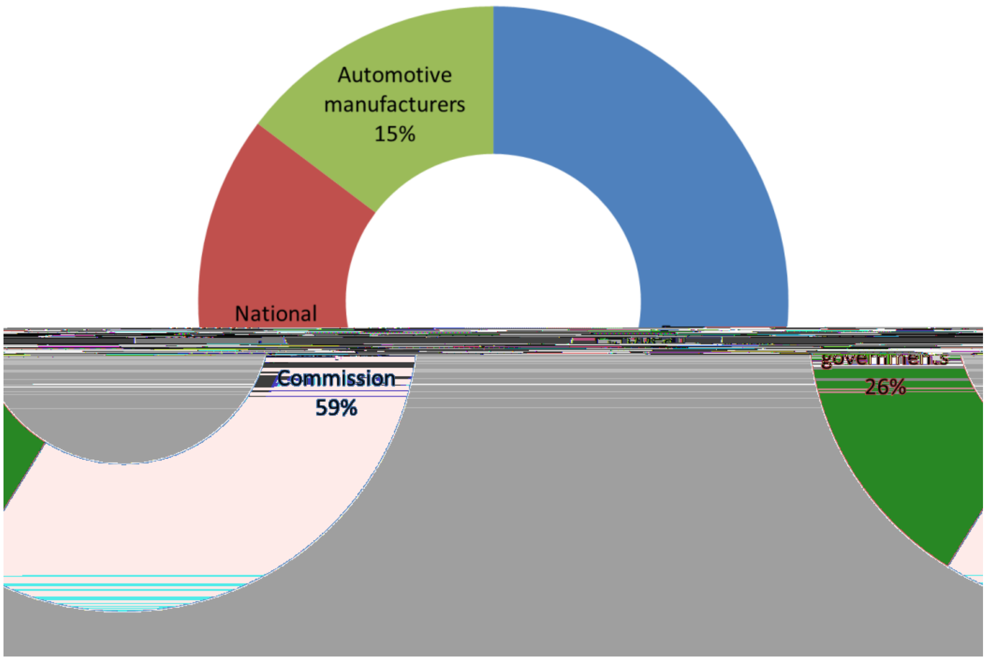

Figure 32: Based on the knowledge of your company, who should have the major role in setting the research agenda with respect to policy measures? (Question 21)

4.3.3. Interview results

This section describes the findings from the interviews. All interviewees believed that distraction was an important road safety topic. All those interviewed seemed to be concerned with this issue and reported at least one measure currently in use to help prevent distraction.

4.3.3.1. Estimates of distraction-related accidents are subjective and varied

Interviewees estimated that distraction caused or contributed to 25% to 40% of all road accidents, describing it as one of the most important or the most important accident cause; there is a consensus that research in this area is scarce, and no data were provided relating to the specific sources of these estimates.

There was also discussion around the need for clear definitions (in the EU) of standards in road user distraction; it is believed that this will help to quantify and clarify the size of the issue.

There were differences between road user types (e.g. car drivers vs. cyclists) and different age groups (e.g. youngsters, elderly) in terms of the importance ascribed to the different types of distraction (e.g. cognitive vs. visual) in causing accidents, and the resulting accident severity. Again interviewees indicated that there were insufficient statistical data for well-founded conclusions on these differences.

4.3.3.2. Mobile devices are still perceived as the main technology distraction issue, and young drivers the main group

There was broad consensus that visual distraction, caused by for example texting and emailing behind the wheel, is the most important type of distraction and that road users in general underestimate the dangers. Young drivers were perceived as a specific group of interest. Some interviewees noted that awareness campaigns often focus on this group for the good reason that they are known or strongly suspected to be more likely to engage in technology-related distracting activities while driving. Others noted that more such campaigns should focus on such issues as smartphone use by younger drivers.

4.3.3.3. National rules and practices

Six of the interviewees focused on a specific Member State in their responses: France, Belgium, Ireland, Austria, UK and Spain. In all these countries handheld calling and texting is banned, and legislation provides for a more generic requirement that drivers should not be distracted from the driving tasks. Fines range between €50 and €135 per incursion.

In all five countries there are regular awareness campaigns concerning road user distraction. These focus mainly on mobile phone use (calling and texting) and often target youngsters. Distraction is covered in driver training in some of these countries[11].

Interviewees indicated that enforcement is an issue, in particular of distractions other than handheld calling.

A researcher associated with the SAFER project indicated that public awareness campaigns are important in combatting road user distraction, but they need to be evidence-based and done in the right way. One example of this is that the dangers of

[11] In the UK, there is currently a trial being undertaken to examine the impact of having directions provided by a satellite navigation system on the practical driving test.

conversing on the phone while driving are controversial, but the dangers of texting are not; the recent Swedish national campaign ("Sluta rattsurfa") is a good example of this.

4.3.3.4. Projects

A number of specific projects and initiatives were mentioned by the interviewees. (Some of the work currently being carried out in this area is discussed further in Section 4.3.3.13 below.)

Both APR (France) and BIVV (Belgium) have projects targeting distraction in professional drivers.

One automotive supplier interviewed is establishing an internal expert group on road user distraction and HMI design, to optimise the exchange of information, test results, and information on external developments (for example in the EU/US/Asia, academia, automotive industry) in the company.

KFV (Austria) is carrying out research to see whether speed-trap-cameras can be used for enforcement of handheld calling bans.

The SafeAPP Working Group of iMobility focuses on ITS apps, in particular apps for safety related traffic information (SRTI) for the automotive industry using the MirrorLink standard. SafeAPP uses the SRTI-message types as starting point. Reducing road user distraction through better design of apps is a key topic for the SafeAPP working group.

4.3.3.5. Need for additional action

Opinions on this topic related quite clearly to the industry or type of organisation being interviewed. While some believed that current measures were appropriate (though in need of further research and enforcement), others (for example the European Cyclist Federation - ECF) focused on the need for additional professional driver training in order to reduce collisions with cyclists. Others in the automotive industry believed that more advanced in-vehicle technology is the key for improved road safety.

Most of the interviewees with a national focus reported that in terms of mobile phone use, legislation and measures are in place now. There also was general consensus that the European Statement of Principles on HMI (ESoP) provides a good basis on which to build over the coming years, that application of ESoP should be promoted, and practical guidelines for the implementation of ESoP should be developed.

Most road safety organisations and the European Cyclist Federation reported that there should be more attention for safe driving in companies. One possible measure could be a mandatory traffic safety plan for each company (through a directive or legislation) identifying potential dangers and mitigation measures.

Automotive suppliers indicated that technology can play an important role in reducing distraction or the impact of distraction. Rear-end collisions caused by distracted road users can be prevented by automated electronic braking systems (AEB). Lane Departure Warning Systems (LDWS) and Lane Keeping Assist Systems (LKAS) can prevent many single vehicle run-off accidents that can be caused by road user distraction. According to the automotive suppliers, the best solution is the right mix of measures of multiple types including better technology, regulation, awareness campaigns, and enforcement.

SAFER states that nomadic devices are an issue, since these devices were not designed for use while driving. Research shows that the use of mobile/smartphones for texting, emailing and so-on causes visual/handling distractions. Safe integration of nomadic devices into vehicles thus has the potential to improve safety. Both navigation and automotive suppliers supported this view. The navigation supplier indicated that nomadic device apps can be made less distracting if these apps have access to CAN-bus data.

The ECF, the automotive and navigation suppliers reported that harmonisation of smartphone and in-car app designs could contribute to lower levels of distraction.

The automotive and navigation suppliers indicated that caution should be taken concerning legislating against specific technologies because the relation between such bans and crash reduction often is unclear and the positive effects of such technologies are underestimated. Furthermore, technology-specific legislation may quickly become outdated as technology changes rapidly. A technology-neutral approach to legislation on road user distraction is desirable, and possible. For example, an interviewee from Sweden highlighted recent research showing that bans on mobile phone use seem to have little effect on crash risk; thus, Swedish authorities have adopted a technology-neutral legislation on road user distraction. No information was provided regarding whether this approach has been more successful in reducing crashes linked to distraction. (See also the literature review in the current project, which comes to the same conclusion regarding the way in which distraction is conceptualised – i.e. at the task level not the device level.)

The SafeAPP representative suggested the development of rules to resolve conflicts in information from multiple sources, for example by adopting the proposed 'time horizon' concept it proposed[12]. This is an important emerging issue as cooperative technology enters the market.

4.3.3.6. Costs and Benefits

There was broad consensus among the interviewed experts that reliable data on the impacts of distraction, and of countermeasures to distraction, are scarce.

The evaluation of awareness campaigns is difficult, and usually impacts are measured in terms of changes in public awareness (instead of the reduction of accidents). However, it is clear that attitudes towards for example speeding, seatbelt use and drink-driving have changed profoundly in some countries over recent decades. Although it is impossible to quantify the impact of awareness campaigns on these changes it appears likely that campaigns, in combination with other measures such as enforcement and improved legislation, can play an important role in changing road user attitudes.

Research by a.o. IIHS (Insurance Institute for Highway Safety, Highway Loss Data Institute, 2011) indicates there is strong evidence that advanced driver assistance systems in general have had an overall positive effect on driver alertness/distraction.

4.3.3.7. Vision

Some of the interviewed experts stated that it is very difficult to assess the impact of new technology on road safety because technological developments outpace research. All agreed that because of the prevalence of distraction in accident causes, and because so little is known about most aspects of driver distraction, it is clear that new technologies will change the situation concerning road user distraction.

[12] A time horizon describes how an application needs to present information to the end-user between the moment of message reception and the moment of passing the incident location.

The automotive suppliers indicated that Vehicle-to-Everything (V2X) data communication is already entering the market. That this technology has the potential to provide a big contribution to road safety was also supported by the representative from SAFER.

Researchers, automotive and navigation suppliers all reported that HMI design plays an important role in limiting distraction. While the automotive suppliers stressed that the industry has been working on safe HMI for a long time, researchers indicated that still relatively little is known on the underlying processes by which HMI should operate safely, in particular for new HMI technologies such as voice recognition.

Interviewees disagreed on some details of the expected impact of new technology on distraction. For example most agreed that automation has the potential to become highly influential, because automation of some driving tasks will necessarily remove some distraction risks. However, some interviewees argued that driver assistance systems can provide a false sense of safety, allowing the attention level of the driver to 'drift away'; most agree however that in the long run automation of driving tasks will probably lead to a significant increase in road safety, but that it is difficult to predict what impact automation will have as it depends on (1) the (SAE) level of automation being deployed and (2) the deployment rate. This, in turn, depends largely on marked pull and legal issues (for example related to liability) which are still largely unresolved.

Currently envisioned scenarios indicate that a great deal of future driving will still be performed by the driver. Moreover, the non-automated vehicles sold today will be on the road for at least 10-15 years. Thus, it seems safe to say is that road user distraction will remain an issue for the coming years.

4.3.3.8. Current barriers

Although most experts reported there are no serious barriers completely blocking the combatting of road user distraction, some inhibiting factors were mentioned.

One inhibiting factor is the cultural aspect of road user distraction; while everybody is expected to be 'online' all of the time, there is limited awareness of the dangers of distraction this causes.

Another factor mentioned was the limited availability of funding for awareness campaigns and shifting policy focus.

Various interviewees pointed out that new technology can become a barrier if not properly implemented and used. As an example, the representative from ECF indicated that Smartphone technology is developing fast, is virtually unregulated and is difficult to regulate. The automotive suppliers warned that there is a tendency to emphasize the negative safety aspects of new technologies while underestimating the safety benefits.

4.3.3.9. Co-operation model

Several experts indicated that the platforms for cooperation in Europe to combat road user distraction are in place. Most experts stated that ESoP provides a good basis for cooperation between all stakeholders in Europe, but some experts indicated that it is not perfect and should be regularly updated and translated into practical implementation guidelines.

All experts encouraged the exchange of experiences and best practices between Member States, and some indicated that EU harmonisation of road safety policies should be based on EC recommendations rather than EU legislative action. ECF emphasised that the safety of vulnerable road users should receive more attention.

Most interviewees agreed that awareness campaigns are an important tool in combatting road user distraction but indicated that, because of the cultural differences in Europe, these should be carried out at a national level. On the European level, interviewees suggested that best practices should be established on how to effectively design, run and evaluate campaigns.

Nearly all experts agreed that research into road user distraction should be a coordinated task in Europe. The certification of electronics and ICT in vehicles by necessity has to be carried out on the EU-level as well, because technological developments are a worldwide phenomenon, and because equipment and vehicles are certified at the EU-level.

The representative of the iMobility SafeApp Working Group stated that the quality of smartphone apps could also be managed through certification, by the suppliers of the smartphone operating systems, the app store operators, or the Car Connectivity Consortium, and that what is crucial is that the interface between device and vehicle is open and transparent to everyone and based on CAN and MirrorLink.

4.3.3.10. Removing EU barriers

Most interviewed experts reported that on the EU-level there are no large barriers that need to be removed and that the ESoP provides a good basis for progress. Several experts suggested that the EC could promote adoption of ESoP by the industry, and that it should be updated to reflect recent developments.

Some experts suggested that technologies that have an obvious and detrimental effect on driver alertness (such as the use of video players by drivers) should be banned in all European Member States.

Others suggested the EC regulations on driver training could be improved to include training on the dangers of distraction, in particular for professional driver training.

Contrary to most experts, the ECF favoured a more stringent approach. It would like the assessment of ESoP to become part of the type approval process and/or of safety regulations and that ‘direct vision’ specifications for lorry designs are included in the type approval procedures.

Most favour measures that block certain uses of mobile phones when moving, through soft measures (best practices); an example would be encouraging mobile phone manufacturers to adopt common HMI principles that block manual input options while moving.

Nearly all agreed that the development and adoption of common definitions, (statistical) measurements and methodologies, and reporting methods for driver alertness and distraction would be helpful. Also, nearly all interviewees agreed that more research was needed into cause and effect of the different types of distractions, and innovative and safe design principles.

The representative of the SafeAPP WG stated that access to CAN-bus data would allow developers of automotive apps to develop safer apps.

4.3.3.11. Research needs

Interviewees unanimously believed that more research is needed in relation to driver distraction, though there was some discussion as to what this research should focus on.

The interviewed researchers emphasize that a common conceptualization and definition of distraction/inattention should be established and that an improved understanding of the problem is needed. This requires a combination of methods: experimental studies and naturalistic driving studies, as well as traditional crash analysis.

The interviewed experts listed the following research needs:

- Impact on road safety of risk compensation (lowering of alertness) in (semi-) autonomous driving
- Auditory/vocal (cognitive) distraction and how it relates to driver performance and crash risk. For example, do head-up displays or voice recognition contribute to or reduce distraction?
- Understanding the role of road user distraction in severe crashes (with severe injuries and fatalities). It is difficult to get anywhere solely based on traditional crash data
- Different pro/cons of HMI design guidelines and verification methods
- Driver's willingness to engage in distraction. What contextual information does the driver use when deciding to engage in distraction? How is the decision to engage influenced by the sociocultural environment, peer pressure, legislation (who's responsible), and the level of automation of driving tasks.
- Effects of distraction countermeasures
- Business models and eco systems of new distraction-preventing technologies.

Research priorities were also mentioned by attendees at the workshop run as part of Task 6:

- Sociological aspects of distraction: What makes drivers willing to take part in distraction activities? How do social norms play a role? Does the need for 'connectedness outweigh risks in the perception of drivers?
- Views of young drivers on driving and distraction: What makes young drivers particularly susceptible to distraction by devices? Which sub-groups of young drivers are particularly at risk?
- Pedestrian distraction studies: What is the exposure of pedestrians to distraction? What behaviours other than crossing the road are affected? How does the increased risk for pedestrians (per unit of travel) compare with that of other road users?
- Distraction/alertness in the transition to automated driving: How long do people need to move from a distracting task to taking over control of an automated vehicle? What are the best ways of alerting drivers in this situation?
- Self-regulation of road users and good driving behaviour: Does behavioural adaptation (e.g. reduced speed) actually reduce risk for some distracting tasks? What are the distraction tasks that cannot benefit from behavioural adaptation?
- Future trends and challenges in distraction: Does the ageing population represent an increased distraction risk? Will 'wearable technology' improve the situation or make things worse?
- New vehicles and distraction: Will new vehicles with different behavioural profiles (e.g. electric bicycles with higher speeds) reduce distraction-related safety margins?

- Business models and eco systems of new distraction-preventing technologies: How can countermeasures be built into the business case? Who will pay for distraction-reducing technologies?

4.3.3.12. Practices and experience from North America

One interviewee stressed the importance of looking into current available research (for example, from the United States) in order to ensure EU funds are not wasted on topics/ issues that have already received attention elsewhere. Some of the practices are listed here.

While texting by drivers is banned in most US states, only 17 states have a general hand-held ban. In Canada all 10 provinces have some form of cell phone/distracted driving legislation banning hand-held use in place.

In the USA several organisations are involved in road safety, often combining their research efforts. On the federal level, the National Highway Traffic Safety Administration (NHTSA) of the U.S. Department Of Transportation, aims to save lives, prevent injuries and reduce traffic-related health care and other economic costs. It does this through research, information and education. The NHTSA developed and hosts the National Automotive Sampling System that stores crash data.

In 2010 the NHTSA adopted a Driver Distraction Program. It outlined measures to improve the understanding of the problem through improved crash reporting and research, and to reduce driver distraction through improved design guidelines. To combat road user distraction the NHTSA operates the http://www.distraction.gov/ web site, targeting teens, parents, educators and employers. It also designated April as the 'National Distracted Driving Awareness Month', and ran a nationwide campaign against road user distraction.

The AAA Foundation for Traffic Safety was founded by the American Automobile Association, a federation of motor clubs throughout North America, to conduct research to address growing highway safety issues. The organization's mission is to identify traffic safety problems, foster research that seeks solutions and disseminate information and educational materials. One of its four priority research areas is Distracted Driving. It carried out a range of studies into different aspects of driver distraction (Strayer et al, 2014; Carney et al, Jun-2015; Cooper et al, 2014; Strayer et al, 2013). Its latest study in this area was a large-scale comprehensive examination of naturalistic data from crashes that involved teenage drivers. It showed that 60% of teen crashes involved distraction (Carney et al, Mar-2015).

The Insurance Institute for Highway Safety (IIHS) is an independent, non-profit scientific and educational organization dedicated to reducing the losses (deaths, injuries and property damage) from crashes. Recent research by IIHS indicates that bans of mobile phone use change behaviour but seem to have little effect on crash risk.

The Alliance of Automobile Manufacturers is a trade group of automobile manufacturers that operate in the United States. In cooperation with NHTSA, academia and other stakeholders, it developed a set of guidelines on distraction for in-car telematics.

According to the representative of SAFER, the USA is ahead of Europe in terms of research into, and dealing with, road user distraction.

The Naturalistic Driving Study of the Strategic Highway Research Program (www.shrp2nds.us) involved 3,000 volunteer drivers that had their cars fitted with cameras, radar, and other sensors to capture data as they go about their usual driving tasks.

Another project in the USA used video-based event-recorded crash data (with in- and outward looking camera footage) collected by the Lytx company from 200,000 vehicles in the US.

4.3.3.13. Overview of existing standards, initiatives and proposals

Standards were recognised as being able to play an important role in harmonising product requirements in terms of road user distraction. They are the building blocks for the description of best practices, agreements between stakeholders, and legislation combatting road user distraction.

This section provides an assessment of whether current (policy) standards, standardisation work items in progress and other initiatives are likely to cover the scope needed to meet the objectives. The information was collected through desk research as well as the interviews with the experts.

The expert interviews showed broad support for ESoP (EC DGMOVE, 2008). ESoP recommends the use of a number of ISO/CEN standards and refers to a number of EC Directives relating to HMI design, as well as a set of regulations of the UN's Economic Commission for Europe (UN/ECE).

Various organisations develop standards that can affect road user distraction, CEN and ISO, but also industry associations and individual companies.

In ISO, the most relevant standardisation work is carried out by the Sub Committee (SC) on Ergonomics of the Technical Committee on Road Vehicles (ISO/TC 22/SC 39). But sub committees ISO/TC 22/SC 31 on Data communication and ISO/TC 22/SC 32 on Electrical and electronic components and general system aspects, and TC204 on Intelligent transport systems, also produce standards that can have a direct or indirect effect on road user distraction.

In CEN, the most relevant Technical Committee is the CEN/TC 278 on Intelligent transport systems, hosting a working group on Man-machine interfaces (MMI) (CEN/TC 278/WG 10). Work of the working groups on Traffic and traveller information (TTI) (CEN/TC 278/WG 4) and eSafety (CEN/TC 278/WG 15) also touch on aspects of road user distraction.

Some of the experts that were interviewed suggested the EC should support certain standardisation efforts. While the automotive suppliers indicated that the ISO/CEN-standards provide a good benchmark to limit road user distraction, researchers and some road safety associations suggested the EC should help in defining European standards in road user distraction, common and statistical definitions for distraction, and how to measure distraction. The SafeApp representative requested support for the standardisation of HMI-tests for certification, including the implementation of the 'time horizon' concept.

The EC adopted a number of recommendations relevant to road user distraction, most notably recommendation 2000/53/EC on safe and efficient in-vehicle information and communication systems of 21 December 1999 (ESoP), and its update (EC DGMOVE, 2008). ESoP requests all interested parties, such as the industry and professional transport-related organisations, to adhere to the updated European Statement of Principles, and the Member States to monitor their application and use. For various reasons the ESoP does not apply to systems that are voice controlled or use head-up displays, or to ADASs.

In the industry the adoption of a specific set of specifications can produce de facto standards. Some of these de facto standards emerged in recent years and can have a direct or indirect effect on road user distraction. Over the past years a number of specifications developed that allow for the integration of nomadic device functionality into a vehicle's audio-visual HMI, allowing for a relatively safe use of nomadic devices while driving. In particular the reduced need for mechanical interaction with the devices and the reduced visual distraction are likely to produce a relative reduction in road user distraction.

A number of working groups and other consortia are undertaking important and valuable work in this area. As previously mentioned, the SafeAPP working group of the iMobility Forum are currently looking at how to build on the ESoP (including dealing with road user distraction). One general issue that has been raised is that access to ITS standards for working groups can be costly both in time and money, and is often a major obstacle in achieving harmonisation. Another example of such an initiative is the Cooperative ITS (C-ITS) Deployment Platform set up by DG MOVE. The aim of this is to address the main barriers and enablers identified for the deployment of C-ITS in the EU. The Car Connectivity Consortium promotes the adoption of the MirrorLink specifications. Apple and Google developed their own set of specifications named Apple Car Play and Android Auto. Many new vehicles support multiple of these competing standards.

4.4. Results – technology-based countermeasures

Distraction countermeasures can roughly be divided into *distraction prevention measures* and *distraction mitigation measures*. Prevention measures are aimed at presenting information in such a way that road-users are not distracted; that is, such measures avoid road users having to focus on information at a point in time when they need all their attention to be devoted to driving. These systems are often referred to as workload managers. Mitigation measures are aimed at mitigating distraction once it has occurred (Regan, Lee & Young, 2008).

A third type of system can be considered as relevant here. *(Adaptive) collision warning systems* do not necessarily counteract distraction per se, but they aim to redirect the driver's attention to an unnoticed situation. *Adaptive* collision warning systems optimize collision warning functionality to the driver-vehicle-environment situation. These systems adapt warnings to an imminent collision to the driver state (eyes-off-the-road, high driving demand etc.), individual differences or traffic conditions (high traffic risk).

A fourth type of system *(Collision mitigation systems*) which are aimed at mitigation of crash consequences, are not considered in this project. This is because these systems are only aimed at reducing the consequences of a crash and are not at all related to the behavioural causes of the accident. Figure 33 shows an overview of real-time system categories, counteracting distraction or alerting the distracted driver and how these systems are positioned in time (after the example given in Regan et al., 2008). Collision mitigation systems are shown to provide a complete overview of real-time systems.

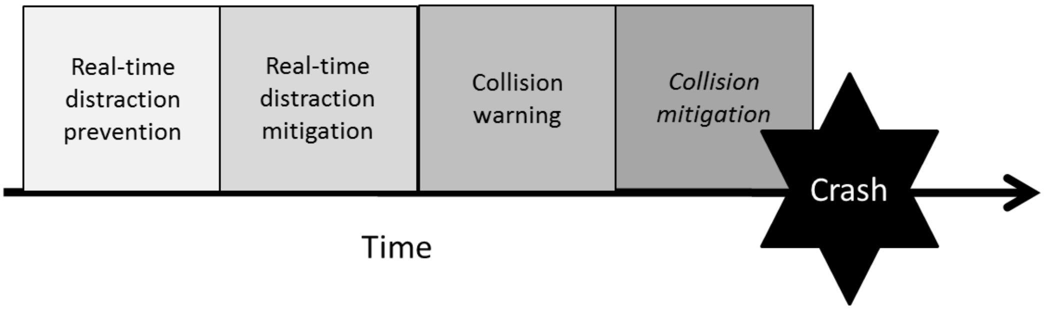

Figure 33: Overview of real-time system categories (Regan et al., 2008)

Besides devices that function in real-time, systems can provide *delayed or retrospective feedback* based on measured driving behaviour, or behaviour possibly negatively affecting the driving task. Delayed feedback on distracted driving behaviour may prevent these behaviours in the future. These systems are aimed at altering behaviour in the long term, rather than influencing immediate behaviour. An example of such a system would be one that provides feedback to a driver on the number of occasions their eyes were off the road for longer than two seconds during the previous journey, and how this might have increased their accident risk.

Besides their function, systems counteracting distraction should be designed in such a way that they themselves do not distract the driver from safe driving. Moreover, other in-car systems, not specifically aimed at alleviating distraction, should have intuitive designs that prevent driver distraction. Therefore, *human-machine interface (HMI) techniques and applications* are also discussed in this chapter.

Whereas *automated driving* systems do not in themselves prevent or mitigate distraction, they allow drivers to be involved in other tasks, without (depending on the level of automation) negatively affecting safe driving. Despite the fact that automated driving is not yet on the consumer market, the necessary technical developments are present and automated vehicles are considered not to be far from implementation. Therefore they are discussed in this chapter as a technical development that can, to a certain extent, counteract distracted driving.

A final system type that has relevance is *cooperative driving.* Such systems can also help with mitigation of distraction, through warnings about road system status.

It is not only car drivers who can be distracted. Motorcyclists, cyclists and pedestrians are also involved in activities that may lead to distraction. Since these groups are more vulnerable than car drivers when involved in an accident, preventing and mitigating distraction is especially important for them, although most technical developments find place within the car domain. Moreover, age groups that are specifically prone to the effects of distraction are children and older road users. Children have a higher tendency to be involved in distracting tasks (Goldenbeld et al., 2012), and also have difficulties in estimating their own level of ability. More so than adults, children do not compensate their traffic-behaviour when involved in tasks that are not directly related to safe movement in traffic (De Craen, 2010). Older people in general experience a reduced information processing capacity which leads to a greater impact of distraction on performance, especially in complex traffic situations.

The following sections 4.4.1 to 4.4.7 describe technologies designed to address distraction in car drivers. Sections 4.4.8 to 4.4.10 consider other road user groups.

4.4.1. Real-time distraction prevention

Real time distraction prevention includes functions that aim to prevent mental overload or distraction from occurring in the first place. This can be done by means of blocking, reducing, prioritizing or scheduling system-initiated information according to the current driving situation or driver state.

There are several solutions that attempt to block or filter a driver's mobile phone while the vehicle is in motion. Some consist of software applications ("apps") installed on devices. They are triggered when the phone's motion exceeds some threshold, so they work only on GPS-equipped smartphones. Other systems are integrated into the vehicle and affect all mobile phones in the vehicle through a small transmitter. Different systems have different ways of blocking or allowing calls. Blocked incoming calls can be stored as voice or text messages; auto-reply responses can be sent by some systems. All systems allow emergency calls. Some allow calls to a few other numbers set in advance. Some block all incoming calls, texts, and emails. Some allow calls when the vehicle is briefly stopped at a red light, while others block calls for up to several minutes after stopping. Some allow geographic areas to be specified within which all calls are blocked. Some allow the user to permit or block calls from specified phone numbers. Each system has a different strategy for addressing the "passenger problem" – whether and how to allow calls by someone in motion who is not a vehicle driver, such as a passenger in a car or a passenger on a bus or train.

The University of Michigan's Transportation Research Institute conducted a study in 2011 to evaluate such a system (GHSA, 2011). Data from 44 employees were collected for nine weeks. During the first and last three weeks the blocking application was inactive, and simply monitored phone use while running in the background (and not restricting any phone use). During the middle three weeks, the software became active, and if it received information that the phone was moving faster than the pre-set speed threshold, phone use was blocked. This included all calling, text messaging, and other interactions with the phone. During the blocking period, participants were allowed to override the blocking for work purposes by entering a short password. At the completion of the sixth week (after the blocking became inactive) each participant was asked to complete an online questionnaire regarding experience with the application. Results showed that:

- Participants answered fewer incoming calls at non-zero speeds during the blocking period.
- Participants placed outgoing calls at lower speeds during the blocking period.
- Participants placed more calls at zero speed during the blocking period.
- Participants overall were neutral in their responses when asked if they received safety benefits from the cell phone filtering/blocking applications.
- Two participants indicated that they gave out their personal phone numbers in order to receive incoming calls while driving when they knew that their work phones would be blocked.
- Very little was seen in the form of positive lasting effect after the applications went back into monitoring-only mode in the last 3 weeks, as no significant differences were found in their behaviours from the first monitoring period to the second monitoring period. Additionally, participants disagreed that they used the phones less in their personal vehicles after this experience.
- The acceptance of the blocking application was low. 40% of the participants did not accept the technology.

The authors also discussed the costs associated with such interventions. The cost incurred through implementing a cell phone filtering/blocking program would mostly be associated with the monitoring and maintenance of the software and the devices. The cost of the software itself is relatively small, and the installation, while potentially time consuming, is a one-time cost. An additional cost, although difficult to assess across different organizations, would likely be the losses in productivity across the organization due to the elimination of cell phone related work activities while driving. Some believe these losses in productivity would be offset by gains in productivity as a result of the reduction in time lost due to crashes (GHSA, 2011).

In another recent study (Ebel, 2015) 29 teenagers were divided into three groups. Cars driven by the first group were left as is, while the second group's cars were outfitted with a video camera mounted to the rearview mirror and linked to an accelerometer. The bi-directional camera kept an interior/exterior record of all high-risk driving events, such as sudden braking or swerving, for later parental/driver review. The third group's cars were outfitted with the camera plus a programmable device that blocked all calls and texts on smartphones linked via an app to the car's ignition. The phone-block device and app are inexpensive and widely commercially available. The camera device was provided by car insurance companies for free to new drivers. Teens who drove cars outfitted with either the camera alone or the camera plus the phone-blocking technology saw their frequency of high-risk driving events drop by almost 80%. This study reported no acceptance levels of the technologies.

Smartphone-based technology is developing very rapidly. Although phone blocking applications are promising and relatively low cost, the acceptance and willingness of a driver to install them voluntarily is likely to be low. This approach is likely to be more successful when initiated by an authority, employers or parents.

Another type of system for real-time distraction prevention is known as a workload manager; when the current state of a driver or driving environment is considered highly demanding, such a system intervenes either on secondary information flows or on driving performance itself. This is therefore a more dynamic and context-sensitive approach than that taken by phone blocking applications.

Such systems can use a range of intervention strategies, such as interrupting a phone call (Saab’s ComSense), applying emergency braking (Lexus’s Driver Monitoring System) or corrective steering (Toyota’s Wakefulness Level Judging System). The former two systems also use acoustic alerts to draw driver attention to the increased workload. In all of these cases, the negative impact of the immediate feedback is that it may impose more workload on a driver in addition to the already highly demanding situation (Donmez et al., 2008). These systems are not solely aimed at distraction, in that they are also focused on noting vigilance deficits associated with fatigue), but the basic principles at play have relevance for distraction effects (i.e. improving driver state by feedback and/or intervening).

4.4.2. Real-time distraction mitigation

In general, distraction mitigation is supported by providing real-time feedback for immediate driving performance improvement. All systems focused on this issue acoustic feedback. Some of them combine different distraction alert modalities such as acoustic and visual (Volvo’s Driver Alert Control and Mercedes-Benz’s Attention Assist) to enhance driver feedback reception. Volvo’s and Saab’s prototypes sometimes use haptic alerts as well. This combination of different feedback modalities is intended to help permit the mitigation of different types and degrees of inattention. For instance, reduced attention levels, cognitive, and visual distraction could be successfully supported by acoustic and haptic alerts but not by visual alone. However, a visual modality of alert can be used for feedback grading; Volvo rates driver attentiveness on a five-bar scale. Another application of the real-time mitigation developed by Seeing Machines (Driver

State Sensor) is system integration into fleet management for later analysis or communication. There are also applications available for smartphones that warn the driver about critical driving behaviour related to distraction e.g. small headways, lane departures, and swerving. An example of such an application is iOnRoad (Figure 34) which uses the camera of the smartphone and video image processing to warn the driver for critical situations and speed limits.

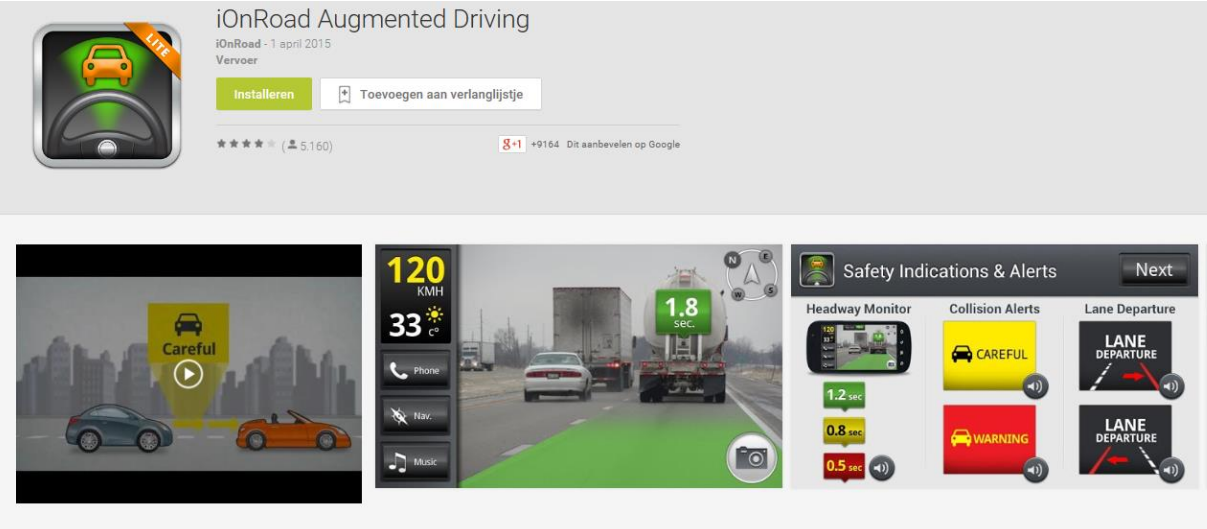

Figure 34. Functionalities and HMI of iOnRoad application. Works with the camera image of a smart phone attached in the windscreen.

4.4.3. (Adaptive) collision warning systems

Collision warning systems do not counteract distraction per se, but they play a role in preventing collisions caused by a loss of attention, possibly in combination with other safety critical factors. The European accident database (CARE) analysis shows that 16% (18,200) of all 1.1 million collisions in 2010 are rear-end collisions resulting in 6% (2,000) of all 30,800 fatalities in the EU ("Answer to a written question - Rear-end traffic collisions in the European Union - E-011477/2011".europa.eu. January 2012).

With adaptive collision warning systems timings of warnings are adjusted to the specific situation and/or driver state. The most important reasons to vary the timings of collision warnings are firstly that response times differ in different situations and secondly that individuals differ in their preferences. The length of response time depends on three factors (Regan et al., 2009):

- The extent to which a driver expects an event (responses to unexpected events take longer)
- The driver state (such as distraction)
- Individual differences.

Without taking into account these variables, a system will potentially present a warning too late. The system might also be experienced as annoying and not relevant in case it warns too early, which may lead to poor acceptance and eventually reduced effectiveness. Distraction-adaptive systems specifically take into account the driver’s actual state, measured by eyes-of-the-road or facial orientation. In these cases earlier warnings are provided to anticipate longer reaction times. In cases where no distraction is detected, and the non-distracted driver is expected to adjust his driving behaviour in time, warnings are cancelled.

4.4.3.1. (Adaptive) Forward Collision Warning

Based on detection of lead vehicles by means of a forward-looking sensor, forward collision systems (usually radar-based) issue a warning to alert the driver if there is an imminent collision risk. These systems can be thought of as being focused on preventing crashes, and on reducing crash severity. These systems are promising since research shows that a loss of forward vision in combination with an unexpected event is the key causal factor in crashes and near-crashes (Dingus et al., 2006). Whereas these systems used to be focused on crashes between motorized vehicles, lately they are also aimed at preventing and reducing the severity of crashes with vulnerable road users. For example carmaker Volvo has, in cooperation with Ericsson, created a safety system that alerts both a driver and a cyclist when they are in danger of colliding with each other. This is achieved through a two-way communication system which pinpoints the proximity of a connected car and a cyclist's smartphone app using GPS. In the case of a critical situation, the car driver will get an alert on the dashboard, whereas a red warning light will flash in the cyclist's helmet.

Numerous studies have been undertaken to assess the effects of such systems on driver behaviour and their effectiveness in preventing or reducing the severity of collisions. In general results are positive, and include a reduction of the number of collisions in distracted drivers in a simulator study (Lee, McGehee, Brown & Reyes, 2002), faster reaction times in cases where a critical situation is detected (sudden breaking of lead vehicle) in a simulator study (Abe & Richardson, 2006), and maintaining safer headways in a field test (Ben-Yaacov, Maltz, & Shinar, 2002). In a more recent study Bueno, Fabrigoule, Ndiaye and Fort (2014) looked in the effects of the system when performing a secondary task. In this driving simulator study participants were required to drive at 90 km/h following a lead vehicle and they were instructed to avoid the possible collisions by decreasing their speed. The FCWS gave a warning (reliable at 75%) to help participants in anticipating a possible collision with a lead decelerating lead vehicle. In the secondary task a set of three words with apparently no links between them was given to the participants. Participants had to guess a fourth word which could be linked to each of the three words. There were two difficulty levels of this task (low and high). Participants were divided into three groups: group SL (System, Low distraction), group SH (System, High distraction) and group NL (No system, Low distraction). The effectiveness of the system according to different difficulty levels of the secondary task was examined by comparing performances of groups SL and SH. The impact of the system when drivers were distracted by a low secondary task was evaluated by comparing performances of groups SL and NL. The (positive) system effects on reaction times, speed and time-to-collisions were dependent on the level of cognitive load introduced by the secondary task. When the secondary (distraction) task was introduced when using the forward collision system, performance decreased. Moreover, performance decreased more heavily when applying a difficult distraction task than when applying an easier (less distracting) one. This finding suggests that the system warning itself requires attentional resources to be properly processed.

While these experimental (simulator) studies provide important insights, field studies provide more knowledge on behavioural effects (including behavioural adaptations) in the longer term under real driving conditions. Eventually such studies should also provide an indication of the reduction in risk of accidents. In the large-scale field operational test in EuroFOT a combination of Active Cruise Control (ACC) and Forward Collision Warning (FCW) was tested. Data indicated that the combination of these two systems can have a positive effect on safety-related driving behaviour. The number of close approaching manoeuvres (and therefore the number of critical situations) was reduced; in case of a highly decelerating lead vehicle for example, warnings presented by the systems provided drivers with sufficient time to react to the critical situation.

In another field operational test, performed by the NTHSA (2005), FCW and ACC were again tested in combination. A number of incidents involving apparent distraction or misjudgement were detected in which the FCW alert probably helped the driver to anticipate a situation. Despite the fact that driving headways increased with enabled FCW however, no change in the rate or severity of conflicts was observed with and without the system. Moreover, drivers were annoyed by the numerous alerts that were experienced as unnecessary. Therefore, despite the fact that the FCW system seemed to help in mitigating distraction or misjudgements, the acceptance of the system appeared to be mixed and it did not impact on the key outcome of crashes or conflicts.

In a more recent field operational test, also performed by NHTSA (Sayer et al., 2011) an integrated safety system was tested (including an FCW system). No effects of the integrated system were found on forward conflict levels and hard-braking frequencies. There was even a small increase in the time spent at time headways of one second or less in the system condition (24%), compared with the baseline(no system) condition (21%). Nevertheless, acceptance of the system was good in terms of satisfaction and usefulness. The majority of the drivers indicated that they would be willing to purchase the system, for a maximum price of $750.

Whereas the above studies involved FCW systems with fixed warning-times, systems have also been tested in which timings are adaptive. In the European AIDE project (Brouwer & Hoedemaeker, 2006) an adaptive FCW system was tested, adjusting timings based on road condition, driving style and driver distraction. Findings from this simulator study indicated that a system adapted to distraction did not show any positive effects in terms of driving behaviour and acceptance. A possible explanation for this finding is that participants managed to perform the distraction tasks very well and could still react to the braking actions of the lead vehicle.

In the SAVE-IT project both Adaptive Forward Collision Warning (AFCW) and Adaptive Lane Departure Warning (ALDW) were studied. In these adaptive systems information about the driver's head pose was utilized in order to tailor the warnings to the driver's apparent level of attention. Results showed that adjusting alerts to the driver's visual distraction may alleviate the tradeoff between providing sufficient warning during periods in which the driver is distracted and annoying drivers when they do not need warnings. By reducing the number of alerts during apparently visually-attentive driving the positive safety effects of FCW (reduction of collisions) was increased and the acceptance of both FCW and LDW was improved.

Collision warning systems specifically aimed at the detection of vulnerable road users are also in development and some are already on the market. Since these systems are fairly recent, not much is known about their effects on driving behaviour and acceptance. However, their potential positive impact on safety is considered important (VRUITS, 2013), although only part of these effects will be directly related to distraction or inattention.

4.4.3.2. (Adaptive) Lane Departure Warning

Lane-departure warning is another system that relies on delivering a warning, in this case when a driver strays across the line boundary or when the distance to the line boundary is considered critical. These systems rely on the detection of lane markings.

Most studies that have investigated the effects of LDW systems show that the system has a positive effect on lateral control and reduces lane departures (Brouwer & Hoedemaeker, 2006, Malta et al., 2012, Alkim, Bootsma & Looman, 2007, Sayer et al., 2011). Besides improved lateral control, In EuroFOT (2012) LDW (in combination with an Impairment Warning system) increased the use of turn indicators. The same finding was reported in a study by Alkim, Bootsma and Looman (2007), as well as the finding that such a system decreased the number of unintentional line crossings. Moreover, a reduction of the variation in lateral position, in order to avoid system warnings, was found. This may have consequences for the driving task, since drivers may have to devote more attention to lateral control (and consequently less to other driving-critical tasks such as the anticipation of road hazards) although it might also entail a lower likelihood of devoting attention to secondary, non-driving-related distracting tasks. Another side effect was that drivers continued driving in the left and (particularly) in the middle lane for a longer time (in the Netherlands this means driving in the offside lanes as they drive normally on the right); it is expected that this will lead to a very small drop in free capacity, and thus only a very small deterioration in traffic flow throughput.

Sayer et al. (2011) reported similar findings. The integrated system they studied (including LDW) had a significant effect on the frequency of lane departures; a decrease in lane departure rate was shown from 14.6 departures per 100 miles during the baseline driving period, to 7.6 departures per 100 miles during test driving (with the system enabled).

4.4.3.3. (Adaptive) Curve Speed Warning

Curve speed warning (CSW) systems issue an alert when speed is estimated to be too high to safely navigate an approaching curve. An adaptive curve speed warning system provides an earlier warning in cases where it believes distraction is present. In the EuroFOT study (Malta et al., 2012) subjective analyses overall showed high satisfaction scores for the (non-adaptive) CSW system. Around 75% of the drivers felt that safety is increased thanks to CSW. In a field operational test study by LeBlanc et al. (2006) no change in curve driving behaviour relating to the CSW system was observed, and system acceptance was mixed. In the AIDE project an adaptive CSW system was found to have a positive effect on driving speed overall (Roland et al., 2007).

No specific data are available for effects of CSW for situations in which the driver is known to be distracted

4.4.3.4. Summary of collision warning systems

Collision avoidance features are rapidly making their way into the new vehicle fleet. Most car manufacturers have introduced collision warning systems that alert the driver or actively interfere in case of a critical situation being detected. Forward collision warning (FCW) systems as well as Lane Departure Warning (LDW) systems are widely available in commercial vehicles and in passenger cars.

Whereas the availability of these systems is still mostly restricted to luxury vehicles, some mass-market vehicles will soon be equipped with collision warning systems (for example, Toyota plans to make crash avoidance systems available on all models by 2017.. Curve Speed Warning (CSW) systems are much less common, partly due to the fact that these systems require reliable GPS data.

In the EuroFOT project estimates of the reduction in accidents by the use of collision warning systems have been made. These estimates are based on usage of the system (if the system is widely deployed) as well as effects on driving behaviour of forward collision warning systems. For example Malta et al. (2012) estimated that between 0.14 % and 5.8% of injury accidents in EU-27 could be prevented by the use of a combination of adaptive cruise control (selects and automatically maintains a selected speed and distance to the vehicle in front depending on his/her preferences) and forward collision warning systems. This is based on a 100% deployment rate in the vehicle fleet and assuming that the indicators tested in EuroFOT correlate with actual crashes. However a precise estimate of the reduction in accidents arising from such systems that are specifically related to distraction is difficult to gauge. Concerning lane departure warning systems, no safety impact could be calculated, based on the EuroFOT data, since the difference in crash-relevant events was not significant. This does however not mean that lane departure warning systems are not useful in the mitigation of distraction, especially since lane keeping tends to be negatively affected by distracting activities (Young, Regan & Lee, 2009). This might not directly lead to an accident but may cause critical situations which negatively affect overall traffic safety.

The collision warning systems discussed in this section appear to have a positive effect on driving behaviour, in terms of surrogate safety measures (lateral position, time headway, speed) as well as safety critical situations and collisions (mostly demonstrated in simulator studies). This is at least an indication that such systems are effective at mitigating distraction. For collision warning systems specifically aimed at avoiding collisions with vulnerable road users, effects are not yet known. Whereas in principle collision warning systems only mitigate distraction, studies show that drivers positively adjust their driving behaviour to prevent alerts, which as noted could mean that attention is being removed from non-driving-related distracting tasks (a good thing for safety) but could also mean that less attention is available for focusing on driving-related tasks such as hazard anticipation (a bad thing for safety). On the other hand, most of these systems can also be switched of, which might be done in daily driving.

Some of the discussed studies are relatively short-term, or even experimental simulator studies, which do not sufficiently take into account possible behavioural adaptation mechanisms, such as increased risk-taking or over-reliance and over-confidence in the systems. Naturalistic studies which take these factors into account show in general that drivers show an increased involvement in tasks not (directly) related to the driving task (for example eating, tuning the radio) but not in situations of a system alert. This could indicate that drivers have an awareness of (complex) situations in which they should be attentive. Nevertheless an increase in tasks not related to the driving task increases the risk of distracted driving, which counteracts eventual positive effects of the systems.

4.4.4. Retrospective feedback systems

Retrospective feedback systems inform drivers about their driving behaviour, either sometime shortly after specific risky (distracted) behaviour has occurred, or post-trip. Such systems are often used in commercial fleets to monitor fuel use (eco-driving) and risky driving. However systems for private drivers are rapidly evolving too. Data on driving behaviour are normally collected with an app or an in-car monitoring device, with feedback provided either through a dashboard interface of some kind or through web-based content. Real-time or concurrent feedback aims to redirect a driver’s attention to the roadway when distraction is indicated by the system. This most common type of distraction mitigation feedback may have an immediate impact on driving performance, but does not necessarily change the actual tendency to engage in distracting tasks. Moreover concurrent feedback can pose additional distractions due to the limited time and mental resources available during driving (Domnez, 2008).

Retrospective feedback aims to change behaviour based on increased insight into prior driving performance without increasing information load during driving. Results from a study of simulated driving by Lee et al. (2013), comparing real-time feedback and retrospective feedback, showed a higher acceptance of retrospective feedback by drivers; moreover, real-time feedback resulted in a decreased focus on the forward roadway (Lee et al., 2013). Domnez, Boyle & Lee (2008) showed however that both real-time and retrospective feedback resulted in faster reactions to lead vehicle braking events. Combined feedback resulted in longer glances to the road. A study by Dijksterhuis et al. (2015) showed that in-car feedback has a slight advantage over retrospective web-based feedback concerning driving speed (speeding, harsh braking, accelerating, and speeding behaviour). These findings were not related to distracted driving, but results might be transferable to feedback concerning distracted driving

Shannon et al. (2012) compared acceptance of two driver distraction mitigation systems (a real-time system and a post-drive system). The in-vehicle distraction mitigation system was designed to provide feedback to drivers about their level of distraction and associated driving performance. Results indicated that a system informing drivers with detailed information of their driving performance post-drive is more acceptable than warning drivers with auditory and visual alerts during driving.

A number of feedback systems (in-car fitted systems or smartphone apps) are available that provide drivers with feedback on their driving behaviour, either concerning safe driving or eco-driving. In the UK as well as in the US these systems are being deployed more and more by insurance companies in order to make insurance fees dependent on customers' driving behaviour. The use of these systems in Europe is however still limited.

Examples of such systems are:

The Netherlands:

- MyJini (https://myjini.nl)

UK:

- Coverbox (http://www.coverbox.co.uk/)
- Ingenie (https://www.ingenie.com/)

USA:

- Snapshot(https://www.progressive.com/auto/snapshot/)
- Drivesense (https://www.esurance.com/drivesense)

None of these systems actually take distracted driving behaviour directly into account (by for example measuring head or eye movements). Behaviour indicated as unsafe (or less safe) by the system could of course be caused by distracted driving (e.g. sudden deviations in lateral position) but an interpretation of the output is required, and in some cases may require additional data to be collected (for example prevailing traffic conditions such as traffic flow or density). Such systems are not deployed with this level of sophistication.

Effects on accident risk are only estimated for the most simple (pay as you drive) systems that simply relate driving risk to driving mileage or style (see e.g. Litman, 2011). Effects of feedback types taking more variables into account are largely unknown and adoption of these systems is limited.

Retrospective feedback has the potential to affect long-term behavioural change if it utilizes techniques known to prompt and support such change; a great deal can be learned from the behavioural change literature in this regard (see e.g. Abraham & Mitchie, 2008). In short, the effectiveness of such systems will depend on the appropriate reward or penalty systems used, system design and user acceptance.

4.4.5. HMI design

Where outright removal of risk is not possible, the Human Machine Interface (HMI) of systems can be designed with reduced distraction in mind. In Europe, North America and Japan, draft standards have already been developed which contain performance based goals which must be reached by the HMI so that the in-car technologies do not distract or visually 'entertain' the driver while driving (e.g., the European Statement of Principles for Driver Interactions with Advanced In-vehicle Information and Communication systems – EsoP). It is important that the development of these standards be closely monitored by relevant authorities and that local vehicle manufacturers and system developers are encouraged to refer to these standards when designing their systems.

In the 'ITS Plan the Netherlands 2013-2017' and the Dutch programme Connecting Mobility, there is the ambition to raise the valuation of the human factors of ITS applications. This will make the technical applications more effective and safe. The first step is the guideline for the safe HMI design of in-car information services. Traffic related information services will be presented more by individual means in vehicles ('in-car') and less by collective means on the road side (e.g. traffic flow information (Kroon et al. (2014)). As a consequence, more and also different types of parties will provide traffic information services to the road user via in-car systems and mobile devices possibly creating a source of distraction. This guideline is meant as a standard for parties that want to deliver good services in respect to the shared collective aim of road safety. Kroon et al. (2014) notes that some of the guidelines regarding HMI modalities are:

Visual distraction

- Information should not lead to glances that exceed two seconds 'eyes off the road'.
- Emotional content should be avoided.
- The display should not present more than four separate types of information units simultaneously in relation to an event.

Auditory distraction:

- Safety related warnings should always be combined with an auditory attention cue.
- A 'neutral' auditory sound should be used when warning about hazardous situations rather than emotion-laden sounds.

Physical interaction

- The information service should not require any manual control input from the driver while driving.
- Upon request of the driver, it should always be possible to turn off the application, and to adjust the brightness of the screen and the volume.
- Furthermore, operating buttons should require minimal visual guidance.
- The display should always be fixed to the car with a holder, preferably in 10 to 20 cm reach of the hand.

Speech based interaction (e.g. Apple's Siri product) is often referred to as an important and indispensable contribution to safer driving. However, the design and implementation of any speech based system will play an essential role for the effectiveness and the safety of voice interaction in the car. An accurate speech recognizer and an easy-to-use voice user interface are the main prerequisites in order to make full use of the potentials of voice interaction, and even good systems can be expected to deliver some distraction deficits.

A recent study illustrates the variability between systems. Cooper et al. (2014) compared different voice based infotainment systems from OEMS. They evaluated systems included a Ford equipped with MyFord Touch, a Chevrolet equipped with MyLink, a Chrysler equipped with Uconnect, a Toyota equipped with Entune, a Mercedes equipped with COMAND, and a Hyundai equipped with Blue Link. Participants completed a series of voice based music functions and phone dialling tasks while driving an on-road course. Each participant drove six vehicles on a seven to nine minute loop through a residential neighbourhood in which they were periodically instructed to dial a 10 digit number, call a contact, change the radio station, or play a CD. All interactions took place using "handsfree" voice systems which were activated with the touch of a button on the steering wheel. Mental workload was also assessed in a single-task baseline drive and during a demanding mental math task, which respectively formed the low and high workload baselines.

In the best case, they found that music functions and voice/contact dialling using Toyota's Entune system imposed modest additional demands over the single-task baseline, whereas those same activities using Chevy's MyLink imposed cognitive load that approached the demanding mental math task (Figure 35). The most critical element of mental workload appeared to be the duration of the interaction, of which the primary contributing factors were the number of steps required to complete the task as well as the number of comprehension errors that arose during the interaction. This indicates that common voice tasks are generally more demanding than natural conversations, listening to the radio, or listening to a book on tape.

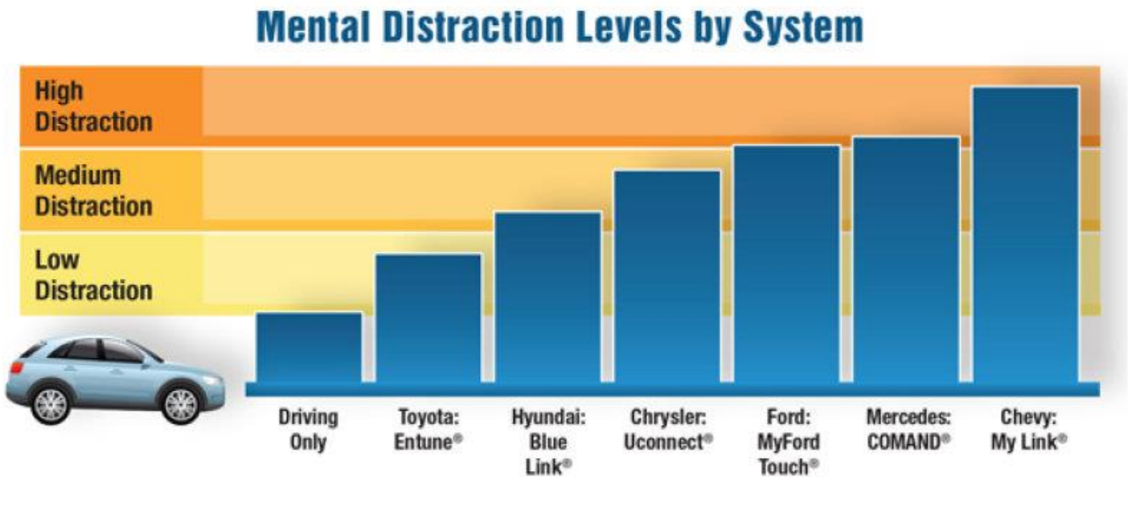

Figure 35: Infographic showing the results of the mental distraction levels of available voice-based systems across six different vehicle types (Cooper et al., 2014).

In another recent study Hoffmann (2015) compared different HMI concepts in terms of usability and driver distraction. Prototypes were developed to perform an online hotel booking by speech while driving. The speech dialog prototypes were based on different speech dialog strategies (a command-based and a conversational dialog). Different graphical user interface (GUI) concepts (one including a human-like avatar) were designed in order to support the respective dialog strategy and to evaluate the effect of the GUI on usability and driver distraction.

Figure 36: Example screen of the conversational dialog with an avatar. When the system asks for input, the avatar points toward entry on the screen (Hoffman et al., 2015).

The results showed that only few differences concerning speech dialog quality were found when comparing the speech dialog strategies. The command-based dialog was slightly better accepted than the conversational dialog, which seemed to be due to the high concept error rate of the conversational dialog. The use of a visual interface impaired driving performance and increased visual distraction. The avatar neither negatively affected driving performance nor increase visual distraction in this study. However the presence of an avatar was not appreciated by participants even though it did not affect the dialog performance.

In summary, HMI design for systems used as countermeasures to distraction can be a source of distraction themselves. If designed well, users' commands can be completed with little error in very few steps, leading to little additional cognitive, visual or manual demand.

4.4.6. Cooperative driving

Besides the transition from manual driving to automatic driving, systems have been developed that change autonomous driving into cooperative driving. This means that drivers receive information from other road users or road side units in order to create safer traffic and to increase flow and efficiency. Here the focus is on cooperative systems that enhance safety, since these systems might help to warn distracted drivers in case of safety critical situations. An example of such a system is an intersection safety system which warns road users for the near presence of other (typically vulnerable) road users. These type of cooperative systems are mostly still under development. However, in Europe in 2013 a list of *day one applications* has been composed. This list contains systems that it is believed will be implemented soon, or at least could be implemented in the near future. Al these systems can be involved in mitigating distraction. Studies indicate that positive effects can be achieved with cooperative systems (DRIVE C2X, PreVENT, SAFESPOT, CVIS – see Table 32 for more information). A generally accepted advantage of cooperative systems is that information can be adjusted to the specific individual, location and situation. Tailored advice is generally held to be better accepted and followed than more general information. Implementation is however complex, since many parties are involved in rolling out such a system.

Table 31: Day one applications (Amsterdam Group, 2013)

Vehicle-vehicle communication	Infrastructure-vehicle communication
1. Hazardous location warning 2. Slow vehicle warning 3. Traffic Jam ahead warning 4. Stationary vehicle warning 5. Emergency brake light 6. Emergency vehicle warning 7. Motorcycle approaching indication	1. Road works warning 2. In-vehicle signage 3. Signal phase and time 4. Probe vehicle data

Table 32: Overview EU projects on cooperative driving

Project	Subject
DRIVE C2X	This project has ended in 2014. Within DRIVE C2X an elaborate evaluation of different cooperative systems has been done, by conducting several field tests throughout Europe. (http://www.drive-c2x.eu/project)
PreVENT	This project (2010-2014) aimed at developing system by which traffic safety can be actively improved. Stand-alone systems as well as cooperative systems were tested: safe speed and safe following, lateral support, intersection safety & vulnerable road users and collision mitigation.
SAFESPOT	In SAFESPOT cooperative systems aimed at improving traffic safety were developed and evaluated. Part of the project consisted of the development of an open and modular architecture and communication platform. (http://www.safespot-eu.org/)
CVIS	CVIS (Cooperative Vehicle-Infrastructure-systems) was aimed at the design, development and testing of technology essential for communication between vehicles and the infrastructure around. (www.cvisproject.org/)

It seems like in some cases the main focus during the evaluation of the cooperative driving applications and systems has been on their usefulness in terms of network performance, rather than on how useful the application is for drivers and their environment. Within the COOPERS project (Böhm et al., 2009), it was shown that the COOPERS system (I2V communication system that transmits high-quality traffic information directly to vehicle groups) can provide a contribution to safe and efficient driving through the information provision and the raising of the attention at critical incidences. Nevertheless the effectiveness in increasing traffic safety (related to distraction and inattention) depends on the way information is communicated to the road user, in addition to the accuracy of the information. In SAFESPOT[13] a safety impact analysis was made for several cooperative driving applications; this estimated a reduction in accidents between 3-26% depending on the functionality and penetration rate of such systems.

As with many vehicle safety technologies, most evaluations of cooperative driving systems have not focused specifically on distraction mitigation.

4.4.7. Automated driving

The SAE levels of automation (2014) provide a common taxonomy and definitions for automated driving in order to simplify communication and facilitate collaboration within technical and policy domains (Figure 37). It defines more than a dozen key terms, and provides full descriptions and examples for each level.

The report's six levels of driving automation span from no automation to full automation. A key distinction is between level 2, where the human driver performs part of the dynamic driving task, and level 3, where the automated driving system performs the entire dynamic driving task.

These levels are descriptive rather than normative and technical rather than legal. They imply no particular order of market introduction. Elements indicate minimum rather than maximum system capabilities for each level. A particular vehicle may have multiple driving automation features such that it could operate at different levels depending upon the feature(s) that are engaged.

System refers to the driver assistance system, combination of driver assistance systems, or automated driving system. Excluded are warning and momentary intervention systems, which do not automate any part of the dynamic driving task on a sustained basis and therefore do not change the human driver's role in performing the dynamic driving task

Increased automation of the drivers' tasks will allow the driver to be less involved in driving and increases the duration that the driver can neglect the driving task without increasing risk. Vehicle automation can greatly diminish the effects of distraction by using technologies already discussed in previous chapters (e.g. FCW, LDW). Automation of the driving task thus allows the driver to be distracted without consequences because in-car technology takes over the role of active driving. However as long as driving has not reached the highest level of automation (SAE level 5) there is a risk that taking control away from the driver leaves the driver with a rather monotonous and generally uneventful monitoring task. Maintaining attention during periods of vigilance is surprisingly difficult (Grier et al., 2003).

Distraction occurring during low workload situations will be more common when vehicle automation is relieving the driver of many demands (e.g. lateral/longitudinal control). Automation thus makes the easy aspects of driving much less effortful, but will likely be fallible and require the driver to intervene in particularly challenging situations, thus potentially making those more difficult because drivers have been 'out of the loop' (Lee, 2014).

Contingency traps reflect situations where drivers fail to attend because the hazards and roadway demands are difficult to perceive. Novice drivers are particularly prone to

[13] http://www.safespot-eu.org/

contingency traps (Fisher, Pollatsek & Pradhan, 2006). Vehicle automation that leads drivers to further disengage from driving will likely exacerbate the effects of these contingency traps. Carefully design of vehicle automation to provide drivers with more rather than less information about the roadway environment might promote greater engagement and mitigate these contingency traps.

With increasing automation the distraction potential of infotainment increasingly depends on how automation worsens or mitigates effects of distraction, and an important aspect is how the transition of control from automatic to manual is supported (Lee, 2014; Merat & Lee, 2012).

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	**No Automation**	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	**Driver Assistance**	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	**Partial Automation**	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	**Conditional Automation**	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	**High Automation**	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	**Full Automation**	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Figure 37: SAE levels of automation

4.4.8. Motorcyclists

Motorcyclists are more vulnerable than users of other motorized vehicles since they lack physical protection, they more easily lose balance, and are less visible for car drivers (Wulf et al., 1989; Chesham et al., 1991; Horswill & Helman, 2003; SWOV, 2014). Despite this, the development of ITS technologies has been mostly focused on cars. Nevertheless, the same types of systems also have potential to increase safety of motorcyclists.

Only few ITS technologies have been developed especially for motorcycles. It is important to design systems with the specific user, with their limitations in mind. For example, within the SAFERIDER project, specifically aimed at the design of safety systems for motorcyclists, it has been stated that HMI design for motorcyclists should be mostly based on haptic HMI element. Visual elements would result in too much distraction, considering the specific driving/riding task of powered two wheelers. Systems that may prevent distraction in motorcyclists are:

- *Advanced Driver Assist*: This system provides riders with information to counteract safety-critical behaviours. This emerging technology is for example used in the Yamaha ASV-2 and ASV-3 in which a range of telematics and vehicle control systems (forward collision warning system, curve speed warning system, speedometer, and navigation system) seek to reduce driving error and workload. This type of system can be helpful in preventing distraction and mitigating the consequences of distraction. To our current knowledge no useful data exist on use and impact.
- *Helmet mounted displays*: In such systems a display is integrated in the helmet, in order to be able to keep the eyes on the road during the use of a navigation system, which prevents the visual distraction associated with ordinary navigation systems. This type of system is still under development (for example: https://livemap.info/)
- *Driver Status Monitoring systems*: Such systems seek to monitor rider state based on variables such as facial detection software or specific driving measures which indicate reduced driver alertness. Such systems are to our knowledge currently not available on powered two wheelers. They are emerging for (commercial) vehicles. Introducing these systems for motorcyclists entails specific application problems, particularly concerning eye tracking devices.

Most ITS currently available on the market are aimed at motorized (typically car) traffic, with vulnerable road users considered as obstacles to be avoided as efficiently as possible. The rising number of systems specifically aimed the safety of vulnerable road users, both in-vehicle and actively to be used by VRUs, not only calls for a comprehensive empirical evaluation of the potential effects of these technological advancements but also for a well-founded assessment of those systems with the highest potential to help improve traffic safety and general mobility.

4.4.9. Cyclists and pedestrians

The use of media players and/or mobile phones while cycling or walking is a common phenomenon (SWOV, 2013). Research has shown that the use of devices while walking or cycling is associated with less safe road user behaviour. Pedestrians and cyclists apparently do not compensate sufficiently for the distraction resulting from the use of devices. With pedestrians, this mainly shows from more hazardous pedestrian crossing behaviour (SWOV, 2013). A survey among cyclists has indicated that the use of devices increases their crash rate by a factor of 1.4 (SWOV, 2013). Since pedestrians do not have to steer a vehicle, they do not experience physical limitations in smartphone use, as other road-users do. Nonetheless their perceptual and cognitive resources (necessary for safe traffic participation) decline dramatically when using their phone.

Besides campaigns to inform people about these hazards of smartphone use in traffic, these very same mobile technologies can (in theory at least) also be used to make pedestrians and cyclists safer, especially to prevent and mitigate smart phone distraction.

Systems aimed at preventing distraction in cyclists are:

- Smartphone applications that block or guide smartphone use during cycling.

  An example of such an application is De Fietsmodus (www.fietsmodus.nl). This application was developed at the request of the Dutch government in order to decrease hazardous smartphone use by bicyclists. With an activated app a cyclist can collect points based on their smartphone use; the less they make use of their smartphone during cycling, the more points they collect . With these points prizes can be won.

- An information system integrated in the cycling helmet.

  An example of such a system is the smarthat (www.smarthat.info). This system, which is still under development, contains an in-helmet display, designed to provide safety-relevant as well as navigation information to the cyclist. This way a cyclist can receive information without having their eyes of the road, therefore potentially decreasing visual distraction.

Zeichner et al. (2014) note some systems that have the potential to increase pedestrian awareness and reduce distraction:

- Smartphone applications that block incoming messages during walking. For example, the Japanese mobile provider Docomo has developed a pedestrian safety mode, that blocks incoming messages and calls while walking.
- Apps that make use of camera technology to see ahead. For example:
  - WalkSafe. Based on the camera input WalkSafe calculates whether moving cars in the environment of the pedestrian provide a threat to a distracted smartphone user.
  - Walk n text. This provides a transparent screen to permit users to see what is going on in front of them (using the camera) while using their smartphone.

Not much is known about the effects of above systems, which will depend largely on the willingness of consumers to actually use them, as well as on their HMI and other features that might affect their effectiveness. One major issue is that these systems have to be activated by users; if users such as cyclists and pedestrians are not conscious of the dangers of smartphone-use while using the roads, it is possible that they will not activate or use the systems (as they see no need to). Therefore, the use of these systems is currently considered to be very limited in terms of road safety.

4.4.10. Older people

Older people can be seen as a vulnerable road user group, although their high rates of collision risk are partly due to low mileage bias (Hakamies-Blomqvist, 2003 – the tendency for older people to drive less, and therefore for a greater proportion of their mileage to be on higher risk roads) and frailty bias (Evans, 2001 – their greater likelihood of sustaining injury in the event of a collision).

Even healthy ageing older drivers can experience a decline of motor, perceptual and cognitive functions, which can affect (driving) performance (Anstey, Wood, Lord, & Walker, 2005). However reduction of the maximum level of performance with age is accompanied with a larger inter individual variability, thus making chronological age unsuitable as a predictor of actual driving capabilities (Donorfio et al., 2008). Whilst the rapid development of technology and more complex and congested traffic conditions mean that the risks of information overload and distraction is important for all road-users, such risks could more quickly develop into critical situations for (some) older drivers since:

- They tend to have relatively little spare capacity to deal with competing activiti
- They tend to be less able to ignore competing activities (i.e. competing activities are likely to be more distracting for older drivers)

- It is more difficult for older drivers to make the trade-off between driving and a competing task to maintain safe driving because of impoverished time-sharing skills

Thus, in terms of the impact of distraction, older drivers need special and specific consideration.

Age-related performance differences are predominately found with respect to *new* or *unfamiliar* skills (skills that were not acquired before old age). The learning of unfamiliar or new skills requires so called 'fluid' intelligence which diminishes with healthy ageing, (Salthouse, 2004). This is apparent in tasks that make extensive demands on the "ability to generate, transform and manipulate information (Salthouse, 2010). Further, it has been suggested that this decline of fluid intelligence is especially noticeable in complex perceptual motor tasks.

Effects of age are usually smaller when knowledge or skills to be learned involve a familiar task domain. Here elderly people can use their stored knowledge (so-called crystallized intelligence) which is stable after the age of 60 (Salthouse, 2004). Technology that taps into new and unfamiliar skills without reference to existing knowledge should be avoided to avoid distraction due to long learning curves to acquire these skills and long reaction times in traffic due to impaired decision making. Furthermore it is known that older people are able to compensate for part or all of their deficiencies by adopting a number of coping strategies (for example adjusting frequency and time of the day of trips to avoid particularly demanding driving conditions – see Eby et al., 2000). One way of thinking about technology in this context then is that it could assist drivers with part of their coping strategies; for example, technology might help with planning a route to avoid particularly demanding roads or traffic types. Also some authors have suggested that driver assistance and information systems might be able to help overcome limitations associated with ageing (Mitchell & Suen, 1997). This would enable older drivers to keep their driver's licence for longer, decreasing their accident involvement and enhancing traffic safety (Davidse, 2007). At the same time however these in-car systems could add to task complexity and demand which could cause distraction. It is known that in older age deterioration of the brain begins primarily at frontal regions (Raz, 2000). These frontal brain regions play a major role in planning, decision making, conflict resolution and executive functions (Craik & Bialystok, 2006). These deteriorations could influence the capability to perform in complex multitask situation such as driving with in car technology. The following table based on results from Ling Suen et al. (1998) and extended for the EU-project GOAL dealing with mobility for the future elder (GOAL 2013). It shows which ADAS help on the certain impairments and driving problems.

Table 33: Car Driver Impairments, Safety Problems, resultant accidents and helping ADAS (based on: Ling Suen et al., 1998)

Impairment	Problems	Accidents	ADAS
Increased reaction time. Difficulty dividing attention between tasks	Difficulty driving in unfamiliar or congested areas	Obey actual traffic signs, traffic control devices, traffic officers or safety zone traffic	Navigation/ route guidance; Traffic information, VMS (see more ITS in M3.2); Traffic Sign Recognition; Hill Descent Control

Impairment	Problems	Accidents	ADAS
Deteriorating vision, particularly at night	Difficulty seeing pedestrians and other objects at night, reading signs	Obey actual traffic signs	Night Vision Enhancement; Adaptive Front Lighting (AFL); Traffic Sign Recognition
Difficulty judging speed and distance	Failure to perceive conflicting vehicles. Accidents at junctions	Turning left at intersections	Adaptive Cruise Control; Speed Regulation System; Curve Speed Warning (CSW); Collision Avoidance System (e.g. FCW, rear-view camera); Lane Change Support; Intersection Assistant
Difficulty perceiving and analysing situations	Failure to comply with yield signs, traffic signals and rail crossings. Slow to appreciate hazards	Yield right-of-way	Traffic Sign Recognition and Warnings; Adaptive Cruise Control; Intersection Assistant
Difficulty turning head, reduced peripheral vision	Failure to notice obstacle while manoeuvring. Merging and lane changes	Turning, turn-around, reverse driving, pulling into a driveway	Blind Spot/Obstacle Detection; Lane Change Warning and Support (Automated lane changing and merging); Automatic Parking (Park Assistant); Rear View Camera
More prone to fatigue	Get tired on long journeys	Keep proper lane	Adaptive Cruise Control; Lane Detection & Tracking (Automated lane following); Lane Departure Warning & Support (LDW); Collision Warning (FCW, CAS)
Some impairments vary in severity from day to day (tiredness)	Concern over fitness to drive	Late or no action, incorrect direction	Driver Condition Monitoring/ Driver Drowsiness Detection

An important challenge for technology to assist older drivers will be to have a user-friendly system approach in which workload and distraction are managed to the specific capabilities of older drivers. These technologies can only benefit older drivers if their design is congruent with the complex needs and diverse abilities of this driving cohort, preferably tapping into existing knowledge frameworks. An intuitive (personalized) human-machine-interface (HMI) where the amount of information given to a driver relates to their individual competence, driving style and conditions will be critical. The technological developments of cooperative driving in conjunction with developments in automated/semi-automated driving will change the nature of the driving task considerably. It is necessary that the needs of older drivers be taken into account, thus ensuring that they are able to cope with such technologies (GOAL, 2013).

Cooperative driving systems also have the potential to adapt to the performance of older drivers by, for example, operating on the assumption of appropriately reduced perception and reaction times. Cooperative signal controlled intersections that adapt in anticipation of potential crashes could be designed with consideration of the multi-tasking difficulties associated with older drivers when navigating intersections.

4.4.11. Behavioural adaptation

In order to estimate the eventual net effects on safety of technical systems, behavioural adaptation that might affect safety (or even counteract the original purpose of the system) needs to be considered.

Behavioural adaptation is defined by Kulmala and Rämä (2013) as "Any change of driver, traveller and travel behaviours that occurs following user interaction with a change to the road traffic system, in addition to those behaviours specifically and immediately targeted by the initiators of the change" (p20). In the road safety context, and in simple language, behavioural adaptations are unintended side-effects which can offset safety gains of new safety systems. A classic example often discussed in the literature is that of studded tyres; Rumar et al. (1976) found that drivers of cars with studded tyres chose higher speeds than drivers without studded tyres, cancelling some of the safety benefit from this technology.

These unintended side effects may concern adjustment of the driving behaviour (higher risk taking) or involvement in secondary behaviours (like eating, drinking, or talking on a cell phone). Findings related to such adaptive behaviours show somewhat mixed results. For example Sayer et al. (2011) did not find an indication of drivers being more involved in secondary behaviours when using the vehicle safety systems. In the EuroFOT project (Malta et al., 2012) an increase of non-driving related behaviour was observed during normal driving when using FCW and LDW, whereas during critical conditions, no such increase was found. In a short three week naturalistic driving study by Touliou & Margaritis (2010) no significant associations of secondary tasks (like singing or turning on the radio) with system warnings were found.

4.4.12. Overview of function and effectiveness of technology-based countermeasures for alleviating distraction

Table 34 provides an overview of the discussed technology-based countermeasures, the most essential system characteristics and the supposed safety effects. The table is based on existing knowledge, expert opinions and was verified in an expert workshop.

Table 34: Overview of system characteristics as well as the expected safety effects of technologies alleviating distraction

System type	System	Road user	Type of countermeasure			Maturity of the technology	Current penetration rate	Acceptance	Safety impact
			Prevention	Mitigation	Warning				
Information Blocking & guiding applications		Professional Driver	•			+++	Medium	Medium	+++
		Private driver	•			+++	Low	Low	+++
		Motorist	•			+++	Low	Low	+++
		Cyclist	•			+++	Low	Low	+++
		Pedestrian	•			+	Low	Low	++
Workload estimator		Driver	•			++	Low	Low	+++
		Motorist	•			+	Low	Low	+++
Real-time mitigation systems		Professional driver		•		+++	Low	Medium	++
		Private driver		•		+++	Low	High	++
(Collision) warning systems	FCW	Professional driver			•	+++	Medium	High	+++
		Private driver			•	+++	Medium	High	+++
		Motorist			•	+	Low	Low	-

System type	System	Road user	Type of countermeasure			Maturity of the technology	Current penetration rate	Acceptance	Safety impact
			Prevention	Mitigation	Warning				
	LDW	Professional driver			●	+++	Medium	Medium	++
		Private driver			●	+++	Medium	Medium	++
		Motorist			●	+	Low	Low	+
	CSW	Professional driver			●	+++	Low	Medium	++
		Private driver			●	+++	Low	Medium	++
		Motorist			●	++	Low	Low	++
Retrospective feedback systems		Professional drivers	●			+++	High	Medium	++
		Private drivers				+++	Low	Low	++
Cooperative systems		Professional driver		●	●	+	Low	Medium	++
		Private driver		●	●	+	Low	Medium	++
		Motorist		●	●	+	Low	Low	++
		Cyclist		●	●	-	-	-	-
		Pedestrian		●		-	-	-	-

System type	System	Road user	Type of countermeasure			Maturity of the technology	Current penetration rate	Acceptance	Safety impact
			Prevention	Mitigation	Warning				
Automated driving technology	Semi-automated	Professional driver		•		++	Low	Medium	++
		Private driver		•		++	Low	Medium	++
	Fully automated	Professional driver	•			+	Low	-	+++
		Private driver	•			+	-	-	+++

System type: referring to previous chapters
System: subdivision of system types referring to previous paragraphs
Road user: Types of road users for which the system is available
Type of countermeasure: indicating whether countermeasures are aimed at prevention, mitigation or warning
Maturity of the technology: - currently in development + not yet mature ++ moderate maturity +++ very mature
Current penetration rate: Low, medium or high penetration of the system in the user population.
Acceptance: user's acceptance of the technology/willingness to use
Safety impact: impact on unsafe situations related to distraction
Examples of available systems: concrete systems that were described in the report

4.5. Summary – countermeasures

The aim of the work reported in this chapter was to examine policy- and technology-related countermeasures to distraction.

After desk-based research was used to identify 34 countermeasures (26 actions and eight policy tools) for consideration, an online survey, interviews, and a focus group and workshop were used to explore these options. A review of the work undertaken previously in the project on the distraction literature and technological developments, along with a review of safety systems (through expert consultation and a wider literature) was undertaken to examine technology-related countermeasures.

In this section we summarise the main findings under individual sub-headings.

4.5.1. Summary of expert ratings

The expert assessment, involving a mapping of those 26 actions and eight tools against their likely impact on road users and types of distraction, suggests relatively high impacts from actions concerning safer product design, better integration between nomadic devices and vehicles and the banning of products (sale or use) that are inherently distracting. It also suggested that legislation and certification are the most effective tools.

4.5.2. Summary of stakeholder ratings

Policy approaches and technologies that respondents (policy makers in the former case, and telematics/ car manufacturers in the latter) reported as being most likely to reduce the risks associated with distraction were:

- Legislation of usage conditions
- Recommendations and best practice
- Public awareness campaigns
- Enforcement
- Voice recognition
- Biometry
- Head-up displays
- Artificial intelligence

All agreed with the expert assessment that HMI design plays an important role in limiting road user distraction. Researchers indicated that still relatively little is known on the underlying processes by which HMI should operate safely, in particular for new HMI technologies such as voice recognition.

There were some differences in ratings by stakeholder group. For example research institutes offered differing opinions from other stakeholders regarding head-up displays and voice recognition (believing them to potentially be damaging to safety by increasing distraction). They also (unlike other stakeholders) rated technologies associated with vehicle automation and artificial intelligence as likely to reduce distraction, and favoured policy approaches associated with mandatory deployment of roadside or central systems, covering distraction in driver training, recommendations based on best practice and stressed the importance of awareness campaigns (in particular targeting professional drivers).

The automotive and navigation suppliers indicated that caution should be taken concerning legislating against specific technologies.

4.5.3. Research priorities

Reported priorities for research (when considering all stakeholders' responses to the survey) were (with examples):

- Voice recognition: How should such systems be designed?
- Night vision: Can such systems present extra information to drivers in such a way as to alert the driver to potential risks, but without being too distracting?
- Biometry: Can systems spot inattention quickly enough to permit useful intervention or alerts? Can they be reliably enough to avoid drivers wanting to turn the systems off (e.g. false alarms)?
- Legislation of usage conditions: How should legislation be designed and worded with the pace of technology development (e.g. new input and output modes) being so quick?
- Public information campaigns: What is needed in such campaigns beyond the provision of information? How can behavioural change techniques help?

Interviewed experts, and attendees at the workshop (Task 6) added that research into the following topics (with some examples given) was also needed:

- Auditory/vocal (cognitive) distraction and how it relates to driver performance and crash risk.
- Sociological aspects of distraction: What makes drivers willing to take part in distraction activities? How do social norms play a role? Does the need for 'connectedness outweigh risks in the perception of drivers?
- Views of young drivers on driving and distraction: What makes young drivers particularly susceptible to distraction by devices? Which sub-groups of young drivers are particularly at risk?
- Effects of countermeasures: Which countermeasures can be shown to really work? What are the relative benefits of enforcement approaches? Can behaviour change approaches work to reduce exposure to distraction?
- Pedestrian distraction studies: What is the exposure of pedestrians to distraction? What behaviours other than crossing the road are affected? How does the increased risk for pedestrians (per unit of travel) compare with that of other road users?
- Distraction/alertness in the transition to automated driving: How long do people need to move from a distracting task to taking over control of an automated vehicle? What are the best ways of alerting drivers in this situation?
- Self-regulation of road users and good driving behaviour: Does behavioural adaptation (e.g. reduced speed) actually reduce risk for some distracting tasks? What are the distraction tasks that cannot benefit from behavioural adaptation?
- Future trends and challenges in distraction: Does the ageing population represent an increased distraction risk? Will 'wearable technology' improve the situation or make things worse?
- New vehicles and distraction: Will new vehicles with different behavioural profiles (e.g. electric bicycles with higher speeds) reduce distraction-related safety margins?
- Business models and eco systems of new distraction-preventing technologies: How can countermeasures be built into the business case? Who will pay for distraction-reducing technologies?

4.5.4. Vehicle automation and assistance systems

Although some interviewees argued that driver assistance systems can provide a false sense of safety, allowing the attention level of the driver to 'drift away', most agree that in the long run automation of driving tasks will probably lead to a significant increase in road safety.

However until we reach the situation when driving is fully automatic, information directed towards the driver has to be managed by increasing awareness of the risks of distracted driving as well as by systems that monitor the timing and amount of information transmitted. The risk of semi-autonomous driving is that it gives drivers opportunities to be more engaged in non-driving-related distractions, while there are still many situations in which the driver has to be alert (for example if a system needs to hand control back to the driver).

On the way to more autonomous driving incoming information to the driver has to be managed. ITS can support the driver in this difficult task. Smartphone-based technology is developing very rapidly. Phone blocking applications are promising and relatively low cost, and have the potential to effectively reduce distracted driving. However, the acceptance and willingness of a driver to install them voluntarily is likely to be low.

Workload managers that take into account the current state of the driver are more promising in terms of acceptability, since information is only blocked in cases where a driver is likely to experience information overload and is thus better matched to the individual circumstances. These systems are still under development, but are promising in preventing unsafe situations, specifically related to distracted driving.

Real time distraction mitigation systems that warn the driver in case of distracted driving (indirectly measured by eye-gaze or specific driving parameters) could be effective since they directly target distracted driving. However these systems only act when the driver is already involved in unsafe driving, which therefore potentially makes them less preferable type of system than a workload manager. Nevertheless, since these systems are still under development, actual effects are largely unknown.

The effects of collision warning systems are much more studied and appear to be positive. However, whereas in controlled studies, effects of these systems on traffic safety are known to be positive, large-scale acceptance in real life driving remains questionable. With adaptive collision warning systems timings of warnings are adjusted to the specific situation and/or driver state.

Retrospective feedback has the potential to affect long-term behavioural change if it utilizes techniques known to prompt and support such change. The effectiveness of such systems will depend on the appropriate reward or penalty systems used, system design and user acceptance.

Cooperative systems provide the opportunity to adjust information to the specific individual, location and situation. Tailored advice is generally held to be better accepted and followed than more general information. This makes cooperative systems promising in reducing distracted driving and highly demanding situations since the information that drivers receive requires less filtering by the driver. Implementation is however complex, since many parties are involved in rolling out such a system.

There is still a long way to go until automatic driving is a reality. In the meantime, it is preferable to prevent distraction instead of 'treating' its effects. The later in the process an intervention is employed, the fewer opportunities there are to prevent an accident. Therefore preventing or mitigating risky driving behaviour is preferable to correcting dangerous driving behaviour. However, systems that monitor driver distraction and manage information that reaches the driver are still under development. Until these systems are more mature, collision-warning systems can be very useful to prevent accidents and these are already implemented and used in private- and professional cars. Nevertheless, the effect of these systems depend on the system-settings, adapted to the individual users, an important component that still needs more research and development.

Besides considering individual systems, with an increasing number of such systems, an integration of in-car and smartphone applications is required and information from these systems have to be matched and managed in order to sustain driving safety. Moreover, individual systems should be developed in such a way that the system itself is not distracting. This can be established by tuning HMI designs to the capacities and preferences of individual users.

5. BEST PRACTICE APPROACHES TO REDUCE THE ROAD INJURY BURDEN OF DISTRACTION

5.1. Aim

The aim of the work reported in this chapter was to identify deployment scenarios for selected interventions, and analyse their costs and benefits.

Deployment scenarios describe the roll-out over the EU of interventions to reduce distraction or increase awareness when using the road, taking into account technical and non-technical aspects that act as barriers or incentives to deployment. Non-technical aspects include, for example, legal, organisational and financial considerations. A qualitative analysis of costs and benefits will describe the societal costs and benefits of an intervention, taking into account the deployment scenario. On the cost side one usually refers to financial costs, but other costs may also be included when applicable (e.g. use of scarce resources such as land). Typically, various types of benefits are considered, such as financial savings, societal benefits in increased traffic safety or decreased pollution or congestion, and personal benefits like time savings.

5.2. Methodology

This section begins by providing an overview of selected interventions. For each intervention a short description is given including the impacts that have been identified in previous tasks. Also a qualitative (and where possible quantitative) review about costs and benefits is given based on available literature. For each intervention barriers to and opportunities for deployment in the EU are discussed. These are gleaned from expert inputs obtained from the stakeholder workshop, and from expert opinion from the partners.

Subsequently the deployment scenarios are ranked in a multi-criteria analysis. In this ranking a "do nothing" scenario is compared with one or more scenarios where measures are taken to speed up deployment. This involves selecting criteria and a scoring system, determining weights and scoring the selected interventions on these criteria. The criteria characterize costs, benefits and ease of deployment, including technological readiness and 'implementability' criteria describing non-technical aspects.

5.3. Results

5.3.1. Review of interventions

Based on the outcome of the previous tasks, and expert opinion from the stakeholder workshop, the following interventions were found to be the most relevant.

1. Awareness campaigns
2. Driver license education
3. Certification of apps and devices
4. Research programmes
5. Workload managers
6. Phone blocking systems
7. (Collision) warning systems
8. Drowsiness warning systems

9. HMI guidelines – product standardisation

The following subsections discuss these interventions one by one. For each one, background information on the impacts from the literature and from the previous tasks is provided, as well as the information on costs, benefits and barriers and opportunities for deployment.

5.3.1.1. Awareness campaigns

This intervention is about making road users aware of dangers of distractions in general, for example making phone calls in traffic. Similar campaigns have been used to raise awareness of the effects of driver fatigue and possible countermeasures, and the negative effects of drinking and driving, and speeding.

Impacts

Awareness campaigns around against drunk or fatigue driving have proven to have a slow but positive effect in general on both moral judgment and behaviour (Peden et al., 2013 and De Dobbeleer, 2009a). Evaluation of campaigns focused on reducing mobile phone usage while driving in terms of their ability to raise awareness and change behaviour at the wheel (and subsequent crash outcomes) is lacking. For other road safety areas, such as drink–driving or speed enforcement, research from WHO (2011) suggests that public awareness campaigns alone have a limited impact on behaviour. Italian media campaigning against distraction (ANIA, 2014) showed that the percentage of accidents caused by distraction dropped only slightly from 17.0% in 2010 to 16.6% in 2012.

Costs and benefits

Costs

For some of the campaigns, like described in De Dobbeleer (2009a and 2009b), numbers on costs were available. When these costs are determined per head of population, estimates vary from €15.95 to €210.86 per campaign per 1000 inhabitants.

Benefits

Most research indicates no significant effects, or minor short term effects, on road safety outcomes. The effect on the long term is unclear. However, a study in Switzerland (Wieser et al., 2010) shows the return on investment (ROI) of public and private road accident prevention interventions between 1975 and 2007 are 1.54 and 9.43 for public prevention programmes only (without investments in safety of road infrastructure).

Barriers and opportunities for deployment

Barriers

WHO research on Traffic Injury Protection (Peden et al., 2013) says distraction countermeasures using publicity campaigns are only effective if combined with other measures such as an increase in enforcement. This way new social norms can be created. When countermeasures are used in isolation, education, information and publicity do not generally deliver tangible and sustained reductions in road accidents.

Opportunities

Awareness of the dangers of distraction is low in all investigated countries. Cost are low. Long term campaigning did cause a fundamental shift in attitudes towards for example seatbelt use, drunk driving and smoking.

5.3.1.2. Driver license education

This countermeasure deals with teaching drivers about the dangers of distraction and mitigation measures during driver license education programmes.

Impacts

Historically, considerable emphasis has been placed on efforts to reduce road user error through traffic safety education – for example, in pedestrian and cycle education for school children, and in advanced and remedial driver training schemes. Although such efforts can be effective in changing behaviour, there is no evidence that they have been effective in reducing rates of road traffic crashes (Peden et al., 2013). Overall however, for the driver license education programmes a slight positive impact is assumed, in line with the effect of public awareness campaigns.

It is best to make a distinction between regular driver training and the (re)training of professional drivers; these are different target groups and reported effects also differ.

Costs and benefits

Costs

No reference costs were available but cost should be limited because these are not ‘new’ countermeasures (updating theoretical exams, training driving instructors and so-on will not be very costly). The training facilities and programmes within which content could be delivered already exist.

Benefits

Typically, it has been concluded that education programmes have no direct impact on traffic accidents (Peden et al., 2013). If indirect evidence is used, a return on investment between 1.54 and 9.8 is reported for public prevention programmes (Wieser et al., 2010). The difficulty here is that these numbers are calculated for a total package of interventions aimed at reducing traffic incidents, of which improved driver training programmes was a part.

A programme to improve road safety of professional drivers of a company, including additional driver training on distraction, reported an 80.9% reduction in insurance claim values. Another company adopting a similar programme reported 20% reduction in collision rates and 25% reduction in paid and estimated cost (Townsend & Galbraith, 2012). However, these results cannot be solely attributed to the driver training. As mentioned in Grayson & Helman (2011), several reviews of both pre-license and post-license driver education programmes provide no measureable effect in reducing road traffic injuries or crashes.

Barriers and opportunities for deployment

Opportunities

Expected costs are low because delivery frameworks already exist. The only challenge is to find a way to focus on the negative effects of distracted driving in an already crowded syllabus.

5.3.1.3. Certification of apps and devices

With this intervention the focus is to amend or establish certification schemes to prevent distracting devices entering the market and to promote product design limiting distraction.

Impacts

It is hard to say what are direct impacts are of certification on the reduction in distraction. However, it is to be expected that certification is a powerful instrument to secure public interests in product design, which can reduce causes for distraction.

Costs and benefits

Costs

No reference costs were available but cost should be limited and can be estimated. E.g. assuming that no simulation or driving tests are required, a basic compliance check in a standardised test tool that simulates sensor input would be sufficient. Development of such a tool will likely be somewhere between 500-1000k€. If the tool is available, the requirements are known and test procedures documented, then a test of a single app should take 10 to 20 man days or about 10-20k€ (including use of the test tool, to be paid by the app developer).

Benefits

No direct evidence can be established because of the long implementation cycles of certification and because it is difficult to isolate from external factors. A positive effect is likely to exist but is expected to be low as single contributing factor.

Barriers and opportunities for deployment

Barriers

Industry might resist mandatory certification because it will increase production costs. Certification would have to cover very different sectors of industry with very different product life cycles (e.g. Smartphone apps versus cars).

Opportunities

App developers, nomadic device and car manufacturer are inclined to make their products safer as long as it does not increase production costs considerably.

5.3.1.4. Research programmes

There is still a need for more research regarding distraction. During the workshops the definition of distraction was not always very clear. Furthermore, the general opinion from especially the car manufacturers and road users was that there has to be more evidence of impacts of fighting distraction, preferably by setting up and evaluating more field operational tests. Research institutes ask for more funding resources.

Impacts

With the help of research more knowledge will be obtained on distraction effects and countermeasures. For example testing new in-car systems in real traffic during field operational test will give us more information about the usefulness of such interventions.

Costs and benefits

Costs

As an example, NHTSA 2015 budget for distraction countermeasures is around 23 million USD, on a total of 850 million USD. This is about 2.7% of the total NHTSA yearly budget. One particular distraction programme, SAVE-IT, had a research budget of 8 million USD. The scope of this study was from setting up distraction architecture frameworks to on road testing and evaluating.

Benefits

During the EU expert workshop on distraction, one of the benefits of performing more research on distraction that was mentioned was the ability to uncover evidence (outcomes of field tests for example) on the effectiveness of particular countermeasures that can be communicated to road users. This could make it more likely that new technologies will be developed and deployed in such a way that acceptance amongst road users will be high. Another benefit could be a more efficient use of financial resources; if it is known which interventions have the most impact, the industry and policy makers can focus on promoting these interventions or systems.

Barriers and opportunities for deployment

Barriers

Research takes time. In order to research effects soundly the interventions have to be evaluated, most likely in a null situation and a situation with the intervention. It is also difficult to assign an effect to the specific intervention; during studies (especially real-world studies) other variables could be of influence, especially when the study takes up a long period of time. In the meantime other technical developments may have been to market ready, making the researched intervention possibly outdated.

Opportunities

Because of the in general increasing number of distraction related incidents, often caused by mobile phone usage, research on countermeasures on these distractions is very important and covers a large group of road users.

5.3.1.5. Workload managers

Prevention measures are aimed at presenting information in such a way that road-users are not distracted; that is, such measures avoid road users having to focus on information at a point in time when they need all their attention on driving. An example of a real-time distraction prevention system is a system known as a workload manager or workload estimator; when the current state of a driver or driving environment is considered highly demanding the system intervenes. Depending on the type of workload manager, it can interrupt a phone call, apply emergency braking or correct steering or just send acoustic alerts to draw driver attention.

Impacts

As discussed in Task 4, countermeasures like workload managers have the potential to improve safety for all road users, not just distracted drivers, because these systems are of the 'prevention' type.

Costs and benefits

Costs

A study by ABI (2014) estimates the price of different car safety packages including driver monitoring systems around €750-800 per vehicle.

Benefits

The aim of a workload manager is to prevent road user distraction. In the literature no explicit benefits in terms of reduction of traffic injuries have been found, but there is a relationship between workload and risk that shows that there is an optimal workload where risk is minimal (Green, 2004). Hence a workload manager can potentially improve safety by optimizing workload, although more research is required to establish the optimal conditions of use.

Barriers and opportunities for deployment

Barriers

User acceptance may be an issue in implementing workload managers. Another issue that was mentioned during the workshop is the fact that when the workload for drivers is too low, they might become bored and distracted as well (Reimer et al., 2009).

5.3.1.6. Phone blocking systems

Distraction by mobile phones can be prevented by blocking or filtering a driver's mobile phone functions while the vehicle is in motion, for example by apps on the phone. They are triggered when the phone's motion exceeds some threshold, so they work only on GPS-equipped smartphones. Other systems are integrated into the vehicle and affect all cell phones in the vehicle through a small transmitter. These solutions can for example block incoming calls, texts and emails while in motion or when moving in a specific geographic area. Each system has a different strategy for addressing the "passenger problem" – whether and how to allow calls by someone in motion who is not a driver, such as a passenger in a car or a rider on a bus or train.

Impacts

It is always difficult to link the effect on (for example) safety to one specific intervention. However in some cases a clear effect can be seen; for example in the United Arab Emirates, the road accident rate dropped 20% in Dubai and 40% in Abu Dhabi and the number of fatalities was reduced after the Blackberry data system went down for three days (Article in the National UAE). It is difficult to say whether this is caused only by drivers not using the phone, but an association clearly exists. More specific effects on behaviour of participants during experiments with phone blocking can be found in Section 4.4.1.

Costs and benefits

Costs

Qualitative estimates of costs are available in some studies (GHSA, 2011 and Funkhouser & Sayer, 2013). The authors in this research found that costs incurred through implementing a cell phone filtering/blocking program for organizations (aimed at employees) would mostly be associated with the following four cost areas:

- Acquisition and subscription costs of the application and any associated equipment
- Education, training and installation
- Maintenance and monitoring
- Effects on productivity

The cost of the software itself is relatively small, and the installation, while potentially time consuming, is a one-time cost. Education and training costs are also onetime costs incurred at the inception of the cell phone filtering/blocking program. Maintenance and monitoring carry long-term costs that will continue as long as the program is in place. Effects on productivity are especially hard to assess; some argue that the loss of productivity of employees results in additional costs, because of the impossibility to use the cell phone while driving, but others argue this as a gain in productivity as result of time reduction due to crashes.

Benefits

On the benefit side little is known, because phone blocking tests results are not available yet. The only benefit known comes from case studies, like the period when the Blackberry data system was inoperable for three days in the UAE, which is believed to have resulted in a reduction of road incidents. Because this intervention is aimed at preventing distraction, the assumed safety impact is high. This can be supported by another study (Ebel, 2015) where the frequency of high risk driving dropped almost 80% during an experiment with teens driving cars with a phone blocking device or video camera’s monitoring their driving style.

Barriers and opportunities for deployment

Barriers

Based on expert opinion, cell phone users will not be very interested in quitting phone use while driving. It could be seen as limiting their connectivity. The study in GHSA (2011) reported that 40% of the participants did not accept the technology; after this study, almost all participants showed the same behaviour regarding phone use while driving as before they took part.

Opportunities

In order to convince road users to give up their phone while in traffic, incentives are required. The Dutch government and telecom providers launched a campaign to instruct bicyclists to not use their smartphone while biking in order to reduce distraction in traffic. Part of the campaign was the Fietsmodus app, which is a free application that monitors usage of a smartphone while riding bike. Cyclists were able to score points by not using their smartphone when cycling. Users with high scores were able to win prizes like movie tickets, t-shirts or a new bike. Given the maturity of the smart phone app technology and the available knowledge about it by the users, this might be an intervention with good opportunities. Similar principles could be used for insurance companies, with insurance costs depending on use of phones and other devices while driving as one behaviour of interest in an overall driving style score.

5.3.1.7. (Collision) warning systems

In a collision or obstacle warning system predictive sensors calculate the likelihood of a crash. An appropriate warning system can inform the driver of dangerous situations in advance or activate a potential pre-crash /crash avoidance system.

Lane warning and guidance systems have been introduced as warning systems to keep vehicles in lane, meaning potentially they can help mitigate the effects of road user distraction. The results of the systems could be positive, if the systems achieve a high (technical) performance and there is a high performance among drivers.

Impacts

In a study on cost benefit assessment and safety impacts of several new technologies (ECORYS, 2006) different earlier studies and tests had been researched. Based on these results the authors found a reduction in collision probability of around 12% for fatalities and 20% for slight and severe injuries for collision warning systems. Also in collision mitigating, there will be positive effects as 8-10% of all accident consequences are expected to shift down one severity class (e.g. from slight injury to avoided).

Systems that raise awareness for specific dangers, e.g. leaving the lane, will lower cognitive load for drivers but warnings may also produce additional distraction. The assumed reduction in collision probability is on average 25% for each fatalities, severe and slight injuries. It is assumed no such devices will be available to pedestrians and cyclists.

Costs and benefits

Costs/benefits

The cost benefit assessment study (ECORYS, 2006) concluded that investment and operating costs are medium/high and low/medium for collision warning systems. It was not possible to estimate a benefit-cost ratio. Therefore break even costs were calculated. If the costs were on average €1200 per vehicle, the benefit-cost ratio would be 1 (break-even). The variable having the most impact on this number is the estimated effectiveness of the technology, whereas market penetration and vehicle lifetime are of minor importance.

For lane change assistance systems. the investment and operating costs are medium and low for lane departure warning systems respectively. Unit prices for combined LDW and LCA are given at €600 (€300 for each) in 2010 and €400 in 2020. Depending on different market penetration rates, unit costs and impact size, this results in a benefit-cost ratio of about 1.1 to 2.4 (the benefits always exceed costs). In a more recent study (TRL, 2008) these numbers were recalculated. Here the authors found a wide spread in BCR. The LDW systems however scored higher benefit-cost ratios than LCA systems.

Barriers and opportunities for deployment

Barriers

The system might also be experienced as annoying and not relevant in case it warns too early, which may lead to poor acceptance and eventually reduced effectiveness. As can be found in NTHSA (2005), drivers can become annoyed by alerts that are perceived to be unnecessary and this can result in systems having little impact on the key outcome of crashes or conflicts. Another problem might be that adding alerts will distract the driver even more (as was found in the SAVE-IT project). Therefore the warnings for the driver has be to tailored, possibly like with the workload manager systems.

Opportunities

At the moment the FCW and LDW systems are only available within the luxury car segment. In order to increase market penetration and thus safety impacts, these systems have to become available to more vehicles.

5.3.1.8. Drowsiness warning systems

Fatigue warning systems have been introduced in cars and trucks in order to reduce the number of (severe) accidents that are caused by driver fatigue. There are several technological solutions for driver fatigue monitoring which can reduce fatigue related crashes:

- Systems that monitor steering patterns (these use steering inputs from electric power steering systems)
- Vehicle position in lane monitoring (these use lane monitoring cameras)
- Driver eye and face monitoring (these use cameras to watch the driver’s face)
- Physiological measurement (these use body sensors like heart rate monitors, skin conductance monitors and muscle activity monitors).

Impacts

Several studies mentioned in ECORYS (2006) and ERSO (2006) indicate an average reduction in fatalities, slight and severe injuries of about 10% when vehicles are equipped with fatigue detectors or driver condition monitoring. Some of the metrics used for detecting fatigued driving may have use in detecting distracted driving too. For example, Tong (2015) demonstrated that such a system could detect eyes-off-road glances based on eye and face monitoring.

Costs and benefits

Costs/benefits

In ECORYS (2006) little was found on solid cost estimates of the fatigue detection systems. It is stated however that investment costs are estimated to be high, while operating costs are low. When taking into account the accident cost, break-even costs can be calculated. In cases where the costs for implementing fatigue detection systems in a vehicle are less than €710, the benefits are higher than the total costs. The results are mostly sensitive to the effect on collision probability, and less to market penetration and vehicle lifetime.

Another study on Intelligent Vehicle Safety Systems (eIMPACT, 2008) calculated BCRs for a number of systems, of which Driver Drowsiness Monitoring and Warning (DDM) was one. This particular system was found as one of the most promising researched interventions with a BCR in 2020 of 1.7-2.1, depending on penetration rate.

Barriers and opportunities for deployment

Barriers

A possible negative effect of in-car warning systems may be that drivers use them to stay awake and drive for longer periods rather than stopping and have a nap (ERSO, 2006). This could be more of a problem with professional (truck) drivers.

Opportunities

Publicity campaigns may help educate the general public about the problem of driver fatigue and possible countermeasures (ERSO, 2006). Just as has been done by not drinking and driving, a fundamental change in behaviour could be accomplished.

5.3.1.9. HMI guidelines – product standardisation

In Europe, North America and Japan, draft standards have already been developed which contain performance based goals which must be reached by the HMI so that the in-car technologies do not distract or visually 'entertain' the driver while driving (e.g., the European Statement of Principles for Driver Interactions with Advanced In-vehicle Information and Communication systems – EsoP).

Impacts

The NHTSA Guidelines (NHTSA, 2012) are expected to have little impact on current vehicle designs. For many current vehicles, the only integrated electronic device that is not required for driving is the stereo system. The NHTSA Guidelines are expected to have a larger impact on future devices that are integrated into vehicles. Research has shown reductions in Total Eyes-Off-Road Time through the use of an auditory-vocal driver-vehicle interface. As a result, NHTSA anticipates that manufacturers may consider relying more on auditory-vocal interactions for task performance in future device designs.

HMI design for systems used as countermeasures to distraction can be a source of distraction themselves, for example when strict guidelines about limited in-car functionality results in users opting for aftermarket devices or smart phones. If designed well, users' commands can be completed with little error in very few steps, leading to little additional cognitive, visual or manual demand.

Costs and benefits

In literature little to nothing was found on costs or benefits on HMI guidelines or product standardisation.

Barriers and opportunities for deployment

Barriers

Regarding the current guidelines, car manufacturers complained during EU workshops that the standards are too political. In this way the guidelines have little effect, because they are unclear or not easy to implement. Also when agreeing on new guidelines takes too much time, there is a threat that drivers will use current devices without proper HMI and become attached to it.

5.3.2. Multi criteria analysis

For the comparison of the different factors that affect driver distraction, a Simple Multi Attribute Rating Technique (SMART) was used. This is a method for a qualitative multi criteria analysis and was used to assess the impacts of the measures identified in the analysis. This method defines criteria and attaches weights to each criterion. The advantage of this technique, compared with the well-known scorecard methodology (with colours indicating qualitatively the importance of the criteria) is that it is possible to distinguish between better and worse values, no matter how small the difference. The SMART methodology normalizes the values in order to make all values comparable (e.g. on a scale from 0 to 10). The values are multiplied by weights to determine the ranking of all the criteria. The higher the total score, the better. This approach makes it possible to attach more weight to the most important criteria. Which criteria are deemed most important in this assessment and which score is assigned per intervention for all criteria, was based on expert judgement.

Furthermore, this method supports a sensitivity analysis on the results. By defining ranges for each weight, the calculation can be performed using alternative sets of weights. This way, the impact of choosing different weights on the robustness of outcomes can be assessed. If the sensitivity analysis results in major shifts in the ranking of measures, this is an indication for collecting additional information on the measures or for further discussion on the weights. This method is often used by policy makers to support a balanced decision making.

5.3.2.1. Criteria

For the scoring the following five criteria have been defined:

Cost-effectiveness

This means how does an intervention score on benefit-cost ratio (if available) or costs in general (if BCR is not available).

Impact size

It could be the case that an intervention scores high on cost-effectiveness, but that the effect on for example safety is only limited. The other way around is also possible. That is why impact size is included separately as one of the criteria.

Ease of deployment

This is one of the criteria that takes into account how much difficulty or resistance there might be to deploy a particular intervention. For example if it is expected to take a long time to deployment, or low penetration might be an issue, ease of deployment is low.

Maturity of technology

This represents the technical state-of-art at the moment regarding implementation. If the intervention is a well proven one, the score is high. If on the other hand the technology at stake is new, the score would be low.

User acceptance

The opinion of the road user matters too. Sometimes interventions may score high on cost-effectiveness and possible impacts, but the user is resistant to using it (for example when the new technology offers less functionality than the old one).

5.3.2.2. Scoring of interventions

The multi-criteria analysis according to the SMART procedure was performed by four different experts from TNO, RappTrans and TRL. Each analysis resulted in weighted scores per intervention. In the end all analyses were weighted to a final score and final ranking of most promising interventions, based on the four individual scorings in the tables that follow:

	Criteria	Cost effectiveness	Impact size	Ease of deployment	Maturity of technology	User acceptance	Sum weights	
	Weight (between 1-3)	2	3	2	1	1	9	
No	**Intervention**	**Score (between 0-10)**					**Total score**	**Weighted score**
1	Raising awareness campaigns	5	2	8	8	6	46	5.1
2	Driver license education	8	8	9	8	8	74	8.2
3	Certification of apps and devices	5	4	4	5	7	42	4.7
4	Research programmes	4	7	8	7	7	59	6.6
5	Workload manager	6	7	7	8	4	59	6.6
6	Phone blocking	7	8	4	3	4	53	5.9
7	(Collision) warning systems	8	9	8	7	8	74	8.2
8	Drowsiness warning	7	7	7	7	9	65	7.2
9	HMI guidelines – product standardisation	5	6	5	6	8	52	5.8

	Criteria	Cost effectiveness	Impact size	Ease of deployment	Maturity of technology	User acceptance	Sum weights	
	Weight (between 1-3)	2	2	2	2	2	10	
No.	**Intervention**	**Score (between 0-10)**					**Total score**	**Weighted score**
1	Raising awareness campaigns	6	2	10	10	8	72	7.2
2	Driver license education	8	4	8	8	9	74	7.4
3	Certification of apps and devices	6	6	6	8	10	72	7.2
4	Research programmes	8	6	10	4	10	76	7.6
5	Workload manager	8	8	6	6	6	68	6.8
6	Phone blocking	10	6	8	10	2	72	7.2
7	(Collision) warning systems	8	8	6	8	6	72	7.2
8	Drowsiness warning	8	10	8	10	6	84	8.4
9	HMI guidelines – product standardisation	8	5	6	5	10	68	6.8

	Criteria	Cost effectiveness	Impact size	Ease of deployment	Maturity of technology	User acceptance	Sum weights	
	Weight (between 1-3)	2	2	1	1	3	9	
No.	**Intervention**	**Score (between 0-10)**					**Total score**	**Weighted score**
1	Raising awareness campaigns	7	5	8	10	10	72	8.0
2	Driver license education	8	5	7	10	10	73	8.1
3	Certification of apps and devices	8	5	5	5	9	63	7.0
4	Research programmes	5	3	6	5	10	57	6.3
5	Workload manager	3	5	1	5	3	31	3.4
6	Phone blocking	9	7	6	8	6	64	7.1
7	(Collision) warning systems	7	8	6	8	10	74	8.2
8	Drowsiness warning	7	7	6	8	7	63	7.0
9	HMI guidelines – product standardisation	8	5	6	7	9	66	7.3

	Criteria	Cost effectiveness	Impact size	Ease of deployment	Maturity of technology	User acceptance	Sum weights	
	Weight (between 1-3)	2	3	2	1	3	11	
No.	**Intervention**	**Score (between 0-10)**					**Total score**	**Weighted score**
1	Raising awareness campaigns	5	3	9	9	8	70	6.4
2	Driver license education	8	7	9	7	8	86	7.8
3	Certification of apps and devices	5	5	5	6	6	59	5.4
4	Research programmes	9	4	10	5	9	82	7.5
5	Workload manager	7	7	6	6	6	71	6.5
6	Phone blocking	6	8	4	4	3	57	5.2
7	(Collision) warning systems	9	10	8	6	8	94	8.5
8	Drowsiness warning	7	7	7	4	6	71	6.5
9	HMI guidelines – product standardisation	6	5	9	9	8	78	7.1

Based on the individual scores in these tables, a final ranking of the (perceived) most effective interventions to target distraction was made (Table 35).

Table 35: Ranking of the interventions

Ranking	Intervention	Average weighted score
1	(Collision) warning systems	8.0
2	Driver license education	7.9
3	Drowsiness warning	7.3
4	Research programmes	7.0
5	HMI guidelines – product standardisation	6.8
6	Raising awareness campaigns	6.7
7	Phone blocking	6.3
8	Certification of apps and devices	6.1
9	Workload manager	5.8

As can be seen from Table 35 (collision) warning systems have the highest score. Driver license education also scores well. Phone blocking measures, certification of apps and devices and workload manager systems are considered to be the least promising interventions based on the SMART multi-criteria analysis..

5.4. Summary – best practice approaches

The aim of this task was to identify deployment scenarios for selected interventions, and analyse their costs and benefits. This was achieved through study of the literature in multiple tasks throughout the project, and through expert input in the second workshop (Task 6). The outcomes of these inputs were used in a multi-criteria analysis to rank the interventions.

The interventions selected for analysis and ranking were:

1. Awareness campaigns
2. Driver licence education
3. Certification of apps and devices
4. Research programmes
5. Workload managers
6. Phone blocking systems
7. (Collision) warning systems
8. Drowsiness warning systems
9. HMI guidelines – product standardisation

The information from the literature was used to make a comparison between systems with a multi-criteria analysis, using the criteria of cost effectiveness, impact size, ease of deployment, maturity of technology, and user acceptance. Scoring on these criteria and weighing was undertaken by experts from the project partners. The scores were weighted to achieve an overall ranking, where user acceptance was given the highest weight by the experts. In the overall ranking, the two interventions receiving the highest ranks were:

- Collision warning systems (forward collision warning and lane departure warning)
- Education about distraction during driver licence acquisition

Most experts had these in their individual ‘top two’ and all experts gave them high scores. Other interventions received lower ranks, for example due to technical immaturity, a long time until effects can be seen, or a difficult stakeholder environment.

6. CONCLUSIONS AND RECOMMENDATIONS

In this study, TRL, TNO and Rapp Trans undertook a number of tasks to answer the following research questions:

- What is the nature and size of the distraction problem in road safety in the EU?
- Which approaches and countermeasures have been used to reduce the road injury burden of distraction?
- Which 'best practice' approaches should be used by EU states in their efforts to reduce the road injury burden of distraction (including an assessment of costs and benefits)?

In this section we state the main conclusions from the work, and the main recommendations.

6.1. Conclusions

Nature and size of the problem

1. There is no standard definition of distraction used in the road safety literature or by practitioners. There is also a lack of standardisation of collision and injury data across the EU, and a lack of information on the proliferation of technologies and their use in traffic. This makes it impossible to quantify with any real certainty the extent of the problem of distraction in road collisions across the EU. A common definition and common approach to coding distraction in collisions is needed.
2. The current estimate for the impact of road user distraction on accidents in the EU is that it is a contributory factor in around 10-30% of road accidents. Current limitations mean that this estimate of distraction related accidents across Europe currently lacks validity and reliability until supported by coordinated data collection.
3. There are a large number of technological developments (17 were identified in the project) that have the potential to have an impact on distraction. There is a lack of objective data on their impact, but based on expert judgement throughout the project a number of consensus findings emerged:
    - Many new technologies have the potential to either increase or reduce distraction, with the level and direction of impact often determined by the way in which the technology is implemented. If poorly implemented, most technologies (even those which are intended to benefit road safety) have the potential to do harm, by increasing road user distraction. The importance of good HMI design was highlighted in all stakeholder and expert engagements, and in the opinion of the project team is a key consideration for future countermeasures.
    - Combinations of technologies might be used to cancel out drawbacks of individual technologies, or to enhance benefits.
    - Even for those technologies which seem most promising in terms of reducing distraction (for example partial automation systems which take driving tasks away from the driver) there is a perceived risk among experts that drivers may find ways to use the spare attentional capacity this presents on non-driving related tasks, resulting in possible issues with situation awareness.
    - It is anticipated that many new technologies will generally have the greatest impact on levels of distraction (increased or reduced) in motor vehicle drivers. However, some will potentially impact on distraction in other road users groups (for example technologies that reduce the need to interact visually with nomadic

devices such as smartphones). All road users will benefit from reduced distraction in other groups, as this will result in them having less risk of being involved in accidents with distracted third parties..

Countermeasures

4. Technologies that are designed (or can be used) to reduce distraction can be thought of as operating either through real-time prevention, real time mitigation, or warning of collisions. Automated driving systems will also provide an important future impact on distraction; however until they are mature and proper research has been undertaken to understand their limitations (for example handing back of control to drivers), distraction prevention and mitigation measures are preferred. An additional consideration however is that while collision warning systems are 'later in the process' of a potential crash, the technologies involved are more mature, and therefore of considerable value in the short term.
5. In terms of countermeasures that can be used to address the problem with distraction, when considering all of the data gathered in the project the key findings were:
    - Legislation, certification, public awareness campaigns and education during the licensing acquisition process (as well as for professional drivers) were seen as the most effective non-technology-based approaches. Awareness campaigns (and education during licensing) should be delivered at the national level, but using a standard EU-led approach.
    - The most promising technologies are voice recognition, biometry, head up displays, artificial intelligence, and (especially from researcher feedback) vehicle automation. Standardised HMI design (for technologies) should also be an important component of an EU-wide approach to distraction.

Best practice approaches

6. The final multi-criteria analysis (based on inputs from all other tasks) concluded that in terms of costs and benefits, the most promising approaches to dealing with distraction are:
    - Collision warning systems (forward collision warning and lane departure warning). These particularly score high on impact and user acceptance, while maturity of technology is high.
    - Education about distraction during driver licence acquisition (and for professional drivers)

6.2. Recommendations

The recommendations from the project are split below into four categories. These are recommendations related to data, technologies, awareness and education, and standards. In all cases, our assessment is that such recommendations would be cost beneficial. Suggestions are made for who should take each recommendation forward, and how.

6.2.1. Data

1. The literature review and review of statistical publications, and stakeholder interviews, confirmed that there is a need for a common definition of distraction, and the related concept of (in)attention. The project team suggests that the following definitions from Engström et al. (2013) are adopted by the EC:

- **Driver inattention:** "…inattention occurs when the driver's allocation of resources to activities does not match the demands of activities required for the control of safety margins." (Engström et al., 2013, p38).
- **Driver distraction:** "…where the driver allocates resources to a non-safety critical activity while the resources allocated to activities critical for safe driving do not match the demands of these activities." (Engström et al., 2013, p35).
- **Activities critical for safe driving:** "…those activities required for the control of safety margins…" (Engström et al., 2013, p17).

It should further be noted that this definition of distraction should be adopted in a way that makes it clear to those using it that it is device-independent, and mode independent (if 'driver' is replaced by 'road users'); instead, it is focused on the tasks people may undertake which lead to distraction.

2. There is also a need for standardised data to be collected on distraction in accident databases across the EU (utilising the definitions above as their basis) so that comparisons across countries can be made on the basis of the same underlying factors. To be able to accurately determine the effects of distraction it will be necessary for countries to begin reporting and investigating distraction in road traffic accidents if they are not already doing so, ideally in a standardised format. Therefore a standard approach to contributory and causal factors involving distraction should be adopted.

   One way in which this could be achieved is for the EC to promote the variable 'Distracted by device' in the Common Accident Data Set (CADaS) from 'Low' to 'High' importance. Additionally, we recommend that the EC considers adding a separate data field to state the extent to which distraction contributed to an accident. Although these types of data are difficult to collect in an objective way, the increasing proliferation of mobile devices that may cause distraction makes it more important that good data are available to track the issue.

   Finally, the EC should build its efforts to encourage member states to include such information in national reporting into the CARE database, and should publish clear annual data on the prevalence of distraction in accidents across EU Member States who are reporting such data.

3. Standardised estimates on the proliferation and use in traffic of distraction-increasing (and reducing) technologies should be undertaken across the EU. Again this will aid in drawing cross-country comparisons. Such measurements would need to be undertaken regularly (ideally annually) and could be run in a similar way to the CARE database, with the EC coordinating and Member States providing data.

6.2.2. Technologies

4. Systems that operate far in advance of collisions (distraction prevention measures such as phone blocking systems and distraction mitigation measures such as distraction warning systems) are preferred to systems that present warnings regarding impending collisions; however the latter technologies are more mature, and have greater supporting evidence for effectiveness (despite not being solely focused on distraction), making them a better short term alternative for policy focus.

   Collision warning systems (such as forward collision warning and lane departure warning) are already being covered in Euro NCAP testing procedures. This is to be welcomed, since these particularly score high on impact and user acceptance in the current study. We recommend that the EC monitors the deployment of such systems so that these data can be used (in combination with monitoring regarding proliferation of distracting technologies, and distraction in accidents) to keep appraising the size of the distraction problem in the EU.

6.2.3. Awareness and education

5. The EC should promote the adoption by Member States of best practices developed in the CAST project on how to effectively design, run and evaluate awareness campaigns. This would provide a benchmark for campaign effectiveness and stimulate the exchange of knowledge and experience on awareness campaigns between Member States. With the EC being a driving force behind Member State campaigns through the exchange of experiences with different campaigns and sharing of good practice, this would nonetheless allow campaign messages to be adapted to culture and language. Any campaigns should include distraction in non-motorised road users.

6. Member States should be encouraged to include distraction content in their driver licensing programmes, and in any training required for professional drivers.

6.2.4. Standards

7. The market of smartphone operating systems is dominated by Apple and Google, both of which have developed technology to use smartphone in vehicles more safely by using the vehicle's HMI features to control the device: Android Auto and Apple CarPlay. Google Android also has some built-in features to limit distraction while driving, notably the (standard) option to respond to incoming phone calls with an automated text reply when moving. Clearly Apple and Google recognise their responsibility in limiting road user distraction. If these companies can be persuaded to adopt common guidelines to further reduce road user distraction this would be a powerful and pragmatic way to reduce road user distraction globally (this could be achieved by signing an MoU to adopt the ESoP).

   The trilateral (Japan, US, EU) group on human factors could provide a good platform to initiate such an initiative. If this approach does not lead to voluntary adoption by the industry within an acceptable timeframe (and distraction by nomadic devices still is an issue) then legislative approaches could be taken (for example through EC electronics certification of nomadic devices).

8. A standard interface for secure mounting and powering of nomadic devices on a central position of vehicle dashboards could limit such distractions such as those caused by sliding and dropping devices and entanglement of power cords. If broadly adopted such a standard would also facilitate enforcement of handheld calling/texting bans. Considering the broad recognition of the importance of distraction in road safety the EC could request industry to establish and adopt such a standard on a voluntary basis, and consider legislative action only if insufficient progress is made.

9. Nomadic devices are often used for navigation or traffic information by car drivers. CAN-bus data would allow developers of automotive apps to develop safer, less distracting apps (for example better switching between day/night view, vehicle type identification to prevent that navigation intended for passenger cars is used in trucks, navigation in tunnels, and so-on). The EC could request the C-ITS Platform to determine what data should be made available on the CAN-bus for nomadic devices.

6.3. Additional findings and considerations

One additional finding from the research could be described as falling outside of the specific scope (as define by the research questions).

In short, there is a need for further research into various aspects of road user distraction. This was a point that emerged through the literature review and review of statistical publications in the current project, as well as from stakeholder interviews. Although the importance of road user distraction as a cause for accidents is broadly recognised, the scientific basis for policies to combat distraction is small. This is in part due to the nature of the topic; accidents are exceptional events and research data are by definition sparse. But a better understanding of the processes behind distraction is important for the development of European and Member State policies dealing with distraction. In particular little is known on distraction that can be induced by the automation of specific driving tasks. In 2010 the US-EU Bilateral ITS Technical Task Force listed the 10 most important research needs. The EC could request the now trilateral group to update the list with the latest insights and use it as a basis for setting the research agenda on road user distraction. On the basis of the findings in this project, the following areas should also be targeted by research:

- Voice recognition: How should such systems be designed?
- Night vision: Can such systems present extra information to drivers in such a way as to alert the driver to potential risks, but without being too distracting?
- Biometry: Can systems spot inattention quickly enough to permit useful intervention or alerts? Can they be reliably enough to avoid drivers wanting to turn the systems off (e.g. false alarms)?
- Legislation of usage conditions: How should legislation be designed and worded with the pace of technology development (e.g. new input and output modes) being so quick?
- Public information campaigns: What is needed in such campaigns beyond the provision of information? How can behavioural change techniques help?
- Auditory/vocal (cognitive) distraction and how it relates to driver performance and crash risk.
- Sociological aspects of distraction: What makes drivers willing to take part in distraction activities? How do social norms play a role? Does the need for 'connectedness outweigh risks in the perception of drivers?
- Views of young drivers on driving and distraction: What makes young drivers particularly susceptible to distraction by devices? Which sub-groups of young drivers are particularly at risk?
- Effects of countermeasures: Which countermeasures can be shown to really work? What are the relative benefits of enforcement approaches? Can behaviour change approaches work to reduce exposure to distraction?
- Pedestrian distraction studies: What is the exposure of pedestrians to distraction? What behaviours other than crossing the road are affected? How does the increased risk for pedestrians (per unit of travel) compare with that of other road users?
- Distraction/alertness in the transition to automated driving: How long do people need to move from a distracting task to taking over control of an automated vehicle? What are the best ways of alerting drivers in this situation?
- Self-regulation of road users and good driving behaviour: Does behavioural adaptation (e.g. reduced speed) actually reduce risk for some distracting tasks? What are the distraction tasks that cannot benefit from behavioural adaptation?
- Future trends and challenges in distraction: Does the ageing population represent an increased distraction risk? Will 'wearable technology' improve the situation or make things worse?
- New vehicles and distraction: Will new vehicles with different behavioural profiles (e.g. electric bicycles with higher speeds) reduce distraction-related safety margins?

- Business models and eco systems of new distraction-preventing technologies: How can countermeasures be built into the business case? Who will pay for distraction-reducing technologies?

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APPENDIX A. EUROPEAN COUNTRIES CONTACTED

Individual road safety experts from the following institutions were contacted personally:

- Belgium, Belgian Road Safety Institute (BIVV)
- Finland, Finnish Transport Safety Agency
- Hungary, Institute for Transport Sciences (KTI)
- Ireland, Road Safety Authority (RSA)
- Malta, Malta Transport Authority
- Netherlands, Institute for Road Saftey Research (SWOV)
- Portugal, National Laboratory for Civil Engineering (LNEC)
- Sweden, Swedish National Road and Transport Research Institute (VTI)
- Czech Republic, Transport Research Centre (CDV)
- Estonia, Estonian Road Administration
- Germany, German Road Safety Council (DVR)
- Greece, National Technical University of Athens (NTUA)
- Poland, Motor Transport Institute (ITS)
- Serbia, Road Traffic Safety Agency
- Israel, Technion – Israel Institute of Technology
- United Kingdom, Transport Research Laboratory (TRL)

In addition, EU CARE experts from the following countries were also contacted via DG-MOVE: Austria, Bulgaria, Croatia, Cyprus, Denmark, France, Italy, Latvia, Lithuania, Luxembourg, Romania, Slovakia, Slovenia, Spain.

APPENDIX B. ADDITIONAL EUROPEAN DATA SOURCES

German In-Depth Accident Study (GIDAS)

GIDAS is the largest in-depth accident data survey in Germany. The data serve as a knowledge base for a wide variety of special-interest groups and is extremely detailed. Approximately 2,000 accidents per year have been analysed since 1999 and reconstructed (in-depth) as part of the GIDAS project in the greater areas of Hanover and Dresden. The project is sponsored by the Federal Highway Research Institute (BASt) and Automotive Research Association (FAT).

BASt.de (2015) gives a detailed explanation of how the information is collected, a summary of which follows:

All relevant information on vehicle equipment, vehicle damage, injuries of persons involved, the rescue chain, as well as the accident conditions at the scene are documented. Interviews of individuals are conducted, which are then followed by detailed surveying of the accident scene based on existing evidence. All information available is retrospectively collected in collaboration with police, hospitals and rescue services. All documented accidents are reconstructed in a simulation program, starting with the accident lead-in phase reactions of involved vehicles. The collision and vehicle end position then follow. Characteristic variables are then determined, including such things as various speeds and changes in direction. Up to 3,000 encoded parameters per accident are obtained in GIDAS according to the document scope.

GIDAS focuses on human accident causes and records the data using specific codes. The coding is structured so that each individual accident type is given a code that consists of four numbers and any accident participant can be assigned multiple codes to represent multiple causation factors.

The code is set up in the following way:

- 1st no. – Group
- 2nd no. – Category
- 3rd no. – Criteria
- 4th no. – Indicator

Firstly, a group is assigned depending on what caused the accident. There are 3 groups: situational human factors (human error), causation factors from the vehicle technology (vehicle malfunction) and factors from environment and infrastructure (external factors).

For the purposes of this study, only the group 'situational human factors' is of interest.

In terms of distraction there are two codes of interest:

- 1-2-01-x (Distraction from inside the vehicle)
- 1-2-02-x (Distraction from traffic environment)

The fourth numbers specify the type of distraction that occurred, i.e. whether they were listening to music or talking on a mobile etc. It would be expected that any records of distraction would be broken down by these fourth factors in order to determine what effect different distracting factors are having.

While the researchers involved were extremely accommodating in our requests, due to other time commitments, it was not possible to access data from this study.

SafetyNet

The SafetyNet Accident Causation System (SNACS) is a methodology developed for the assessment of casual factors in each accident of the European Road Safety Observatory (ERSO) accident causation database (Talbot et al., 2013). This is a database containing the details of individual crash investigations within the European Union (EU). Data were collected by teams of trained accident investigators in several EU member states:

- Vehicle Safety Research Centre (VSRC), Loughborough University, UK.
- Netherlands Organisation for Applied Scientific Research (TNO), Delft, Netherlands.
- Chalmers University of Technology (Chalmers), Gothenburg, Sweden.
- Accident Research Unit at Medical University Hanover (ARUMUH), Hanover, Germany.
- The Finnish Motor Insurers' Centre (VALT/FMIC), Helsinki, Finland.
- Department of "Idraulica, Trasporti, Strade", University of Rome (DITS), Rome, Italy.

Each team comprised specialists in accident investigation, psychology and human factors.

The teams were available to attend the scenes of accidents within a short time following its occurrence, usually with the co-operation of local police forces. This way it was possible for investigators to arrive with the vehicles involved untouched and any participants still present at the scene. Data were then collected relating to vehicles, accidents, participants and the road environment. Depending on how appropriate the investigator felt it to be, the road users were also sometimes interviewed as part of the investigation.

Of the data recorded in the database, there were approximately 200 variables collected for each case with roughly 500 pieces of information per case being obtained, describing environmental, vehicle and driver factors.

There are 1,005 individual accident cases contained in the SafetyNet Accident Causation Database involving 1,828 vehicles and 2,422 road users.

The only distraction information obtained were those figures reported in the literature review. Other information was not available as at the time of writing as sufficient permissions had not been granted by the required work package participants to provide access to the data.

APPENDIX C. TASK 2 FULL TABLES

C1 - Technological developments: Categories, pre-conditions, drivers and constraints

No.	Name	Category	Pre-Conditions	Drivers	Constraints
1	Sensor data	Sensor	Availability of GNSS networks	Mass-production of sensors lowers unit costs Mass-production of CPU lowers data processing costs	Data processing and interpretation capacity
2	Non-flat display technologies	MMI improvements	Further development required Mass-production to be started	Demand for design Practical uses, e.g. Steering wheel display	
3	Tactile sensor technology	MMI improvements		Mass-production lowers unit costs New technology (OLED, quantum dot) improves in-car use	Not suited for driver-vehicle interaction
4	Dynamic dashboard	MMI improvements	Reliable algorithms to determine driver information needs	Data availability (vehicle sensors, biometry)	Effective only if HMI is properly designed and content of sufficient quality is available
5	Head-up display	MMI improvements	Reliable algorithms to determine driver information needs	Mass-production lowers unit costs New display technology improving usability	Favourable weather conditions
6	Night vision	Sensors	Line-of-sight required	Ageing of population	Information needs to be interpreted and only relevant information conveyed to the driver

No.	Name	Category	Pre-Conditions	Drivers	Constraints
7	Haptic/tactile feedback	MMI improvements	Availability of relevant sensor data End-user acceptance	Lowering of sensor costs Automation of vehicle controls	
8	Increased vehicle connectivity	Connectivity	Broad adoption of common interface standards Critical mass of connected/cooperative vehicles	Lowering of data communication costs (incl. Roaming) Broad adoption of WIFI-P standards	
9	intra-nomadic-vehicle connectivity	Connectivity	Broad adoption of common hardware and software interface standards, sufficiently large installed base	Consolidation in the smartphone OS market	
10	extra-nomadic-vehicle connectivity	Connectivity	Broad adoption of common hardware and software interface standards, sufficiently large installed base	Consolidation in the smartphone OS market	
11	Biometry	Sensor	Acceptation by end-users	Safety requirements of drivers and road authorities	
12	Voice recognition	MMI improvements	Proper microphone configuration in vehicle	Improved voice recognition and interpretation software	Background noise. Headsets can hamper auditory perception of road users
13	Virtual reality	Interpretation	Broad deployment of connected and/or cooperative technology	Increased availability of sensor data Increased connectivity of road users	Perception capacity of drivers
14	Artificial intelligence	Interpretation	Economic processing power and data storage capacity	Availability of sensor data	

No.	Name	Category	Pre-Conditions	Drivers	Constraints
15	Conditional automation (SAE=3)	Automation	Acceptance by end-user	Safety and comfort requirements of drivers	
16	High automation (SAE=4)	Automation	Legal embedding of automated driving Acceptance by end-user	Safety and comfort requirements of drivers	
17	Full automation (SAE=5)	Automation	Legal embedding of automated driving Acceptance by end-user	Safety and comfort requirements of drivers	

C2 - Assessment potential of technological developments per distraction type

No.	Name	Visual	Auditory	Biomechanical	Cognitive	Assessment
1	Sensor data	-	-	-	1	Only indirect effects. More sensor data can contribute to better information to the driver but also to an information overload, hence slightly positive contribution to 'cognitive' distraction
2	Non-flat display technologies	-1	0	-	0	Does not contribute to better awareness of relevant info for drivers, if not properly used might lead to extra distraction
3	Tactile sensor technology	-1	-1	1	0	Does not contribute to better awareness of relevant info for drivers, but can replace more distracting HMI-components, if not properly implemented might lead to extra distraction and tempt driver to interact while driving
4	Dynamic dashboard	1	0	0	0	Allows effective presentation of the most relevant information, contributing to less visual

No.	Name	Visual	Auditory	Biomechanical	Cognitive	Assessment
						distraction, but the changing of content also causes cognitive task switch costs
5	Head-up display	1	0	0	0	Allows effective presentation of the most relevant information, contributing to less visual distraction, but the overlay of information also causes cognitive task switch costs
6	Night vision	-1	0	0	0	Allows drivers to better focus on traffic and potential dangers but can lead to distraction when information is not properly filtered, interpreted and presented
7	Haptic/tactile feedback	0	0	1	0	Allows more direct influencing of driving behaviour, but amount of information that can be transmitted is limited
8	Increased vehicle connectivity	-1	-1	-1	1	Only indirect effects. Data from other vehicles and cloud lead to better awareness of traffic and potential dangers, but may also contribute to distracting and conflicting information being presented to the road user.
9	Intra-nomadic-vehicle connectivity	1	1	1	-1	Encourages use of features of the nomadic device while driving, but discourages direct interaction with the device.
10	Extra-nomadic-vehicle connectivity	-1	-1	0	1	Might lead to extra distraction from false alarms. If working properly raises awareness when relevant allowing the road user to focus on other (safety) aspects of traffic.
11	Biometry	-	-	-	2	No additional user distraction, raises awareness only when appropriate and thereby reduces cognitive distraction
12	Voice recognition	1	-1	2	1	Can replace manual operation of controls leading to less visual and biomechanical distraction but is likely to lead to some additional auditory distraction
13	Virtual reality	-1	-1	0	1	Only indirect effects. Leads to additional visual and auditory distraction but it can contribute

No.	Name	Visual	Auditory	Biomechanical	Cognitive	Assessment
						to better awareness of traffic and potential dangers.
14	Artificial intelligence	-1	-1	0	2	Only indirect effects. AI can replace certain tasks of drivers allowing them to focus on traffic and potential dangers, but if not properly implemented may lead to additional distractions.
15	Conditional automation (SAE=3)	-1	-1	0	2	Automation might lead to additional distraction but it allows drivers to better focus on traffic and potential dangers. Partially automated driving can cause auditory/visual and biomechanical distraction in case the driver has to take over again in case of an emergency
16	High automation (SAE=4)	0	0	-1	2	Allows drivers to better focus on traffic and potential dangers but can lead to absentmindedness.
17	Full automation (SAE=5)	0	0	0	3	Allows drivers to be distracted without risk

C3 - Assessment potential of technological developments per road user type

No.	Name	Drivers (private vehs)	Professional drivers	Motorcyclists	Pedestrians	Cyclists	Children	Elderly	Assessment
1	Sensor data	1	1	1	-1	-1	-1	-1	More sensor data allow drivers of motorised vehicles to better focus their attention. For pedestrians and cyclists more information will more likely lead to more distraction than produce benefits.
2	Non-flat display technologies	-1	-1	1	1	1	-1	-1	Allows presentation of information on wearables and handlebar devices, if properly used can improve cognitive awareness for cyclists and pedestrians
3	Tactile sensor technology	-1	-1	-2	-2	-2	-2	-2	Has the potential to distract, in particular of two-wheelers and pedestrians
4	Dynamic dashboard	2	2	2	-	-	-	-	Less visual distraction for motorised road users, not relevant for other road users
5	Head-up display	2	2	1	0	0	-1	-	Less visual distraction for vehicle drivers. Might lead to additional distraction for other road users
6	Night vision	-1	-1	-1	-1	-1	-1	-1	Similar effects for all road users on distraction. The impact of distraction is estimated to be higher than the cognitive benefits.
7	Haptic/tactile feedback	2	2	3	1	2	1	1	Can provide targeted awareness for relevant traffic situations, in particular for (motor)cyclists

No.	Name	Drivers (private vehs)	Professional drivers	Motorcyclists	Pedestrians	Cyclists	Children	Elderly	Assessment
8	Increased vehicle connectivity	2	2	2	-	-	-	-	Better awareness of traffic allows identification of, and warning for, specific traffic dangers for motorised vehicle users
9	Intra-nomadic-vehicle connectivity	1	1	1	-	-	-	-	Encourages use of nomadic device while driving, but discourages direct interaction with the device.
10	Extra-nomadic-vehicle connectivity	0	0	0	1	1	1	1	Might lead to extra distraction from false alarm but can raise awareness when relevant, in particular for vulnerable road users
11	Biometry	2	2	1	0	0	0	0	Raises awareness only when appropriate and thereby reduces cognitive distraction. Has a positive impact on vehicle drivers only because the technology is difficult (but not impossible) to apply to the other road users.
12	Voice recognition	1	2	3	0	0	0	0	Can replace manual operation of controls, in particular useful for motorcyclists. Non-motorised road users can also benefit when using a proper headset but headsets also limit auditory perception
13	Virtual reality	0	0	0	0	0	0	0	Leads to additional distraction for all road users types, but better awareness of traffic allows identification of, and warning for, specific traffic dangers contributes in a positive sense to the expected level of distraction. Overall it is estimated these opposing effects cancel each other out for all road user types.
14	Artificial intelligence	1	1	1	0	0	0	0	Raises awareness only when appropriate and thereby reduces cognitive distraction. Less relevant for non-motorised road users as

No.	Name	Drivers (private vehs)	Professional drivers	Motorcyclists	Pedestrians	Cyclists	Children	Elderly	Assessment
									they have less sensors.
15	Conditional automation (SAE=3)	1	1	-	-	-	-	-	Automation might lead to additional distraction but it allows drivers to better focus on traffic and potential dangers. Only relevant for vehicle drivers.
16	High automation (SAE=4)	2	2	-	-	-	-	-	Allows drivers to better focus on traffic and potential dangers but can lead to absentmindedness. Only relevant for vehicle drivers.
17	Full automation (SAE=5)	3	3	-	-	-	-	-	Allows drivers to be distracted without risk. Only relevant for vehicle drivers.

C4 - Literature review for technological developments by distraction type

No.	Name	Visual	Auditory	Biomechanical	Cognitive
1	Sensor data				
2	Non-flat display technologies				
3	Tactile sensor technology				

No.	Name	Visual	Auditory	Biomechanical	Cognitive
4	Dynamic dashboard				
5	Head-up display	"Drivers engaging in visually and/or manually complex tasks have a three-times higher near-crash/crash risk than drivers who are attentive." (Klauer et al., 2006)			
6	Night vision				
7	Haptic/tactile feedback				
8	Increased vehicle connectivity				“93 percent of all lead vehicle crashes involved inattention to the forward roadway as a contributing factor " (Neale et al., 2005)
9	intra-nomadic-vehicle connectivity	"Information should not lead to glances that exceed 2 seconds eyes off the road." (Rijkswaterstaat, 2014)	"Safety related warnings should always be combined with an auditory attention cue." (Rijkswaterstaat, 2014)	"electronic device use was only weakly related to serious incidents" [teenage drivers] (Goodwin et al., 2012) "...the dialling task was relatively high in term of total conflicts and was associated with the largest number of near crashes." (Neale et al., 2005) "Physical interaction with the driver should be minimized." (Rijkswaterstaat, 2014)	"Mobile phone use has ... negative impacts because drivers ... need to divide their attention between using the phone and driving (cognitive distraction). Because it leads to cognitive distraction, hands-free calling does not provide significant safety benefits to hand-held calling." (SWOV, 2012) "increased risk appears to be similar for both hand-held and hands-free phones, suggesting that it

No.	Name	Visual	Auditory	Biomechanical	Cognitive
					is the cognitive distraction that results from being involved in a conversation on a mobile phone that has the most impact upon driving behaviour, and thus crash risk" (WHO, 2011)
10	extra-nomadic-vehicle connectivity				"of great interest to the safety of the VRU, in the first place: … VRU Beacon Systems (VBS) in the future." (Eisses, 2011)
11	Biometry				
12	Voice recognition	"US Naturalistic Driving-studies (ND-studies) show that in particular activities that provide most visual distraction are most dangerous. " (SWOV, 2013)		"64% of drivers operate their navigation systems while driving. This can lead to critical driver distraction." (Eisses, 2011)	"The data suggest that voice-based interactions in the vehicle may have unintended consequences that adversely affect traffic safety" (Strayer et al., 2014)
13	Virtual reality				
14	Artificial intelligence				"Information can be presented best when the workload of the primary task is low (tedious for some, to a long, time), e.g. driving on a quiet road with low traffic density and activity for a long time. In complex situations, depending on the complexity of the infrastructure, the

No.	Name	Visual	Auditory	Biomechanical	Cognitive
					traffic density and the speed that is being driven, information provided to the driver should be minimized; less urgent messages should be postponed." (Rijkswaterstaat, 2014) "Information presented is non-ambiguous, valid and reliable. Information should be recognizable and consistent with legal traffic signs and signals and local road side information. Information is credible and aims for high acceptance and compliance." (Rijkswaterstaat, 2014)
15	Conditional automation (SAE=3)				"In general, systems that assist the car driver in the driving task will influence the behaviour of the driver. Whereas the primary effect is likely positive, adverse effects – e.g. less attention to a part of the driving task 'because the system will take care of it' – may reduce the net impact on safety." (Eisses, 2011)
16	High automation (SAE=4)				
17	Full automation (SAE=5)				

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C5 - Literature review for technological development by road user type

No	Name	Drivers (private vehs)	Professional driver	Motor-cyclists	Pedestrians	Cyclists	Children	Elderly
1	Sensor data							
2	Non-flat display technologies							
3	Tactile sensor technology							
4	Dynamic dashboard							
5	Head-up display							
6	Night vision							
7	Haptic/tactile feedback							
8	Increased vehicle connectivity							
9	Intra-nomadic-vehicle connectivity	"Wireless devices (primarily cell phones, but also including PDAs) were the most frequent			"A simulator study subsequently showed that students who were distracted	"Both handheld and hands-free calling resulted in lower speeds, a disturbance of auditory	Inattention to the driving task is also commonly found among young drivers, who are more	"young drivers and cyclists appear to be engaged more frequently in all sorts of

No	Name	Drivers (private vehs)	Professional driver	Motor-cyclists	Pedestrians	Cyclists	Children	Elderly
		contributing factor for lead vehicle events, followed by passenger-related inattention" (Neale et al, 2005)			by internet on their smartphone exhibited more dangerous road crossing behaviour than participants that were not". (SWOV 2013)	perception, and a delayed response to auditory stop signals". (SWOV, 2013) "However, cyclists listening to music do fail to notice auditory stimuli more often." (SWOV, 2013)	easily distracted from the driving task (Freeman et al., 2012)	distracting activities than middle-aged or elderly drivers." (Stelling & Hagenzieker, 2012)
10	Extra-nomadic-vehicle connectivity						"The majority of young adolescents have a mobile phone, smartphone or music player. Compared with older age groups, youths also use these devices very much while they are cycling. In addition, they make different use of their mobile devices." (Hoekstra et al, 2013)	
11	Biometry	"In the more distant future it might be possible for detection						

No	**Name**	**Drivers (private vehs)**	**Professional driver**	**Motor-cyclists**	**Pedestrians**	**Cyclists**	**Children**	**Elderly**
		equipment to warn when the attention level is too low." (SWOV, 2012)						
12	Voice recognition					"the odds of being involved in a bicycle crash were estimated to be higher for teen cyclists and young adult cyclists who used electronic devices on every trip compared to same age groups cyclists who never used these devices. " (Goldenbeld et al, 2012)		
13	Virtual reality							"an overwhelming of cognitive capacity for some elderly drivers" (Elslande et al., 2012)
14	Artificial							

No	Name	Drivers (private vehs)	Professional driver	Motor-cyclists	Pedestrians	Cyclists	Children	Elderly
	intelligence							
15	Conditional automation (SAE=3)		"Distraction, loss of concentration and fatigue are more important in the occurrence of accidents than previously thought. A high task load for the driver also is an important factor that negatively affects the driving behaviour." (Buck Consultants, 2013)					
16	High automation (SAE=4)							
17	Full automation (SAE=5)							

APPENDIX D. MAPPING OF REFERENCE SOURCES TO ACTIONS AND TOOLS

No.	Description	Source
1	Banning use or sale of specific devices / equipment	Eisses, 2011; Goldenbeld et al, 2012; Goldenbeld et al, 2010; Goodwin et al, 2012; Hoekstra et al, 2013; Regan, 2012; SWOV, Apr-2012; SWOV, Aug-2013; SWOV, Sep-2013
2	Mandatory fitment of specific devices in vehicles	Eisses, 2011; Goodwin et al, 2012
3	Legislation of usage conditions	Eisses, 2011; Regan, 2012; SWOV, Oct 2012; SWOV, Sep-2013
4	Mandatory deployment of roadside / central systems	Eisses, 2011
5	Financial support	Eisses, 2011
6	Financial support of deployment	Eisses, 2011
7	Certification	Eisses, 2011
8	Fiscal incentives	Eisses, 2011
9	(Financial) support of standardisation	Eisses, 2011
10	Recommendations / best practices	Eisses, 2011; Regan et al, 2008
11	Public awareness campaigns	Buck Consultants, 2013; Eisses, 2011; Goldenbeld et al, 2012; Goldenbeld et al, 2010; Hoekstra et al, 2013; Ichikawa & Nakahara, 2008; SWOV, Feb-2012; SWOV, Oct-2012; SWOV, Aug-2013; SWOV, Sep-2013; Tertoolen, 2014; DaCoTa, 2012
12	MoU with MS, SPs, car manufacturers	Eisses, 2011

No.	Description	Source
13	Insurance incentives	Eisses, 2011
14	Mandatory messages in communication	Eisses, 2011
15	Supporting action: enforcement	Buck Consultants, 2013; Eisses, 2011; Goldenbeld et al, 2012, Goldenbeld et al, 2010; Hoekstra et al, 2013; SWOV, Sep-2013
16	Promote fitment of devices/equipment, e.g. through EuroNCAP	Eisses, 2011
17	Support / promote research	Eisses, 2011, DaCoTa, 2012
18	Increase attention to distraction in driver license programmes	Freeman et al, 2012; Klauer et al, 2006; SWOV, Oct-2012; SWOV, Sep-2013; DaCoTa, 2012
19	Mandatory useage requirements, e.g. Handsfree calling	Goldenbeld et al, 2012, Hoekstra et al, 2013; SWOV, Sep-2013
20	Promote manufacturers to make their (handheld) products less distracting in traffic. E.g. Lower sound volume when nearing a crossroads in audio players	Goldenbeld et al, 2012; Hoekstra et al, 2013; Regan, 2012; SWOV, Dec-2010; SWOV, Oct-2012; SWOV, Sep-2013; DaCoTa, 2012
21	Enhancements to infrastructure to mitigate the effects of distraction, e.g. Rumble strips	Hoekstra et al, 2013; SWOV, Feb-2012
22	Reward good behaviour, e.g. smartphone app rewarding non-use while moving	Hoekstra et al, 2013; Tertoolen, 2014
23	Promote development of distraction mitigating technology, products	SWOV, Oct-2012; SWOV, Sep-2013
24	Promote deployment of distraction mitigating technology and products	SWOV, Oct-2012; Klauer et al, 2006
25	Mandatory deployment of distraction mitigating technology and products	SWOV, Oct-2012; Regan, 2012

No.	Description	Source
26	Limit visual distraction beside the road, e.g. Limit number of billboards, regulate size, distance to road, form and content of messages.	SWOV, Apr-2012; SWOV, Sep-2013; DaCoTa, 2012
27	Promote development of distraction detection and warning technology and products	SWOV, Feb-2012
28	Promote deployment of distraction detection and warning technology and products	SWOV, Feb-2012
29	Mandatory deployment of distraction detection and warning technology and products	SWOV, Feb-2012
30	Mandate manufacturers to make their (handheld) products less distracting in traffic. E.g. Lower sound volume when nearing a crossroads in audio players	SWOV, Oct-2012
31	Mandatory mounting requirements for nomadic devices	DaCoTa, 2012
32	Headphone bans; in vehicle, on bicycle, when walking	DaCoTa, 2012
33	Usage restrictions on devices by passengers (e.g. TV not visible to driver)	DaCoTa, 2012
34	Develop workload metrics	DaCoTa, 2012

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