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Title: A dual-experiment based on immersive simulation to study futures interactions between pedestrians and automated vehicles

T. BELLET, S. LAURENT, I. HOANG, B. RICHARD, J.C. Bornard

Abstract: With the development of Automated Vehicles (AVs), interaction between cars and pedestrians will soon become a challenging issue for road safety. In today's world, human drivers and pedestrians interact using non-verbal communication based on eye contacts to manage their interactions and to clarify their intentions. Several studies have shown the importance of this informal communication to avoid accident. This is particularly true in the case of road crossing decisions when priority rules are not clear (e.g., absence of zebra crossing). Introduction of automated vehicles on public road will radically change the situation: car occupant could be totally inattentive to the traffic scene (when sleeping or being visually distracted by a secondary task, for instance), and it is also possible that there are no human on board. In this context, pedestrians will have to discover new behaviours of vehicles, to learn new rules to make their crossing decision, and to train themselves in new practices to interact safely with automated cars. Because automated cars are not currently traveling on public roads, one way to study this issue is to use immersive simulation to allow real humans to « practically experience » (even if in a virtual way) future interactions with such automated vehicles. In order to study how interactions between pedestrians and automated vehicles may look like in the future, and how road safety may be potentially affected by the AV behaviour, an immersive experiment was implemented in the SUaaVE european project (SUpporting acceptance of automated VEhicle, H2020). Forty participants were involved in this experiment: 20 young mean-aged of 25.1 years old, and 20 elderly people mean-aged of 67.5 years old (50% women for each group). They all have to experience a set 8 driving scenarios (in a randomized order), from two different points of view: As an AV passenger (to experience on a driving simulator how the AV reacts when facing pedestrians' road crossing) and as a pedestrian (equipped with a virtual reality headset and located on a pavement, facing a continuous flow of a randomized number of approaching vehicles). For each scenario, they have to assess the safety of the different braking strategies implemented by the AV. Results show that AV braking strategies stopping the car at 5 meters of the pedestrians are assessed as more safe than braking stopping closer to them (i.e. 2 meters). In addition, a common hierarchy of the safety of the different AV yielding manoeuvres is identified for all the participants. Nevertheless, significant differences are found between the two groups: compared to young people, who assessed the safety of the AV manoeuvres similarly whether as a pedestrian or as an AV passenger, older participants have a tendency - as pedestrians - to misperceived and/or misestimate the "velocity/brutality" of some AV braking manoeuvers (typically for AEB emergency braking strategies).

Titre : Une expérimentation reposant sur la simulation immersive pour étudier les interactions futures entre piétons et véhicules automatisés

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Résumé: Avec le développement des technologies d'automatisation de la conduite, l'interaction entre les véhicules et les piétons pourrait devenir un défi majeur pour la sécurité routière. Aujourd'hui, les conducteurs et les piétons interagissent au moyen de contacts visuels pour gérer leurs interactions et clarifier leurs intentions. De nombreuses études ont montré l'importance de cette communication non verbale pour gérer le risque et éviter les accidents. C'est particulièrement le cas dans les situations de traversée de rue/routes, lorsque les règles de priorité ne sont pas explicites (i.e. en l'absence de passage piéton). L'introduction de Véhicules Automatisés (VA) sur la voie publique est susceptible de modifier radicalement la situation. En effet, le passager du VA pourrait être totalement inattentif à la situation de conduite (s'il dort ou s'il est distrait par une tâche secondaire, par exemple), et il est également possible qu'il n'y ait pas d'humain à bord du VA. Dans ce contexte, les piétons seront confrontés dans l'avenir à de nouveaux comportements des véhicules, et ils devront apprendre à les analyser pour prendre leur décision de traverser et interagir en toute sécurité avec les véhicules automatisés. Comme les VA ne circulent pas encore sur les routes, une façon d'étudier cette question est de recourir à la simulation immersive pour permettre aux usagers d'aujourd'hui "d'expérimenter pratiquement" (de façon virtuelle, mais tangible) ces futures interactions avec les VA de demain. Afin d'étudier ses situations et les risques pour la sécurité routière susceptible d'être induits par l'introduction des VA sur les routes, une expérience immersive a été mise en palce dans le cadre du projet européen SUaaVE (SUpporting acceptance of automatic VEhicle, H2020) . Quarante personnes volontaires ont participé à cette expérimentation : 20 jeunes (âge moyen de 25,1 ans) et 20 personnes âgées (âge moyen de 67,5 ans), avec 50 % de femmes pour chaque groupe. Tous ont été invités à vivre 8 situations d'interactions VA-Piéton (hors passage piéton) selon deux points de vue différents : en tant que passager d'un AV (simulé sur simulateur de conduite) afin d'expérimenter différentes réactions du VA lorsque celui-ci décide de s'arrêter pour laisser traverser un piéton, et en tant que piéton (équipé d'un casque de réalité virtuelle) situé sur le trottoir et en attente de traverser, confronté à un flux continu de véhicules en approche parmi lesquels l'un d'enter, le VA, va s'arrêter pour leur céder le passage. Pour chaque scénario, les participants devaient évaluer la sécurité des différentes stratégies de freinage mises en œuvre par le VA pour s'arrêter. Les résultats obtenus montrent que les stratégies de freinage du VA stoppant la voiture à 5 mètres des piétons sont évaluées comme plus sûres que les freinages s'arrêtant plus près d'eux (à 2 mètres seulement). De plus, une hiérarchie commune, concernant la sécurité perçue des différentes stratégies de décélération du VA, a été pu être identifiée pour tous les participants. Néanmoins, des différences significatives apparaissent entre les deux groupes : par rapport aux jeunes, qui évaluent de manière similaire la sécurité les freinage de l'AV en tant que piéton comme en tant que passager, les plus âgés ont en revanche tendance - en tant que piétons - à mal percevoir et/ou à mal évaluer le risque associé à certaines manœuvres de freinage engagées par le VA (i.e., freinages d'urgence de type AEB, correspondant à des réactions non justifiées dans le contexte des scénarios étudiés pour cette expérimentation).

1.Introduction

With the development of Automated Vehicles (AVs), interaction between cars and pedestrians will soon become a challenging issue for road safety. This study aims to anticipate these future interactions during road crossing situations. Indeed, when introduced on public roads, AVs will coexist with conventional vehicles as well as with pedestrians. In order to contribute to a safe traffic system and to ensure the public acceptance of AVs, the one key challenge is to investigate how pedestrian will understand and assess AVs decision to yield when they are waiting on the pavement with the willingness to cross a road.

In the world of today, with a view to achieve safe interactions, pedestrians and car drivers need to have a shared understanding and awareness of a given traffic situation. Situation awareness (SA) was defined by Endsley as "*perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future*" (Endsley, 1995). As a mental representation of the traffic situation, SA plays a key role for risk assessment and decision making when interacting with other road users (Bellet *et al*., 2009). In the case of a misinterpretation of others' intentions, critical accidents involving pedestrians may occur (Habibovic & Davidsson, 2012). The Fatality Analysis Reporting System revealed that more than twenty-five percent of pedestrians' fatal crashes were due to a lack of communication or, more precisely, a wrong assumption of others' actions (National Highway Traffic Safety Administration, 2017). Road-crossing situations involve a complex decision-making process based on several factors (Lévêque *et al.*, 2020). In this context, and especially when ambiguities remain regarding priority rules (i.e., non-signalised crossing), pedestrians and car drivers tend to interact using non-verbal communication (e.g., facial expressions, eye contacts, gestures, and body movements) in order to clarify their intentions. The importance of such informal communication, namely interpersonal communication, to ensure roadway safety has been widely documented in the field of traffic psychology. Schmidt & Färber discussed the crucial road of eye contact between pedestrians and drivers (Schmidt and Färber, 2009). More precisely, they showed that pedestrians willing to cross a street usually look at the approaching vehicle, to make sure the driver sees them. Once their eye contact is returned, pedestrians suppose they were noticed by the driver, and that a mutual understanding was achieved. Thanks to a study carried out with a large sample of pedestrian behaviours, similar conclusions were reached by Rasouli *et al.* who found that, in the context of non-signalised crossings, more than ninety percent of the pedestrians studied gazed at oncoming vehicles before crossing (Rasouli *et al.*, 2017).

All these studies clearly indicate that eye contact between pedestrians and conventional car drivers is a crucial element to manage situational risks, to support pedestrians' decision making, and to increase their safety while crossing roads. Therefore, a key concern regarding the introduction of AVs on public roads is that they may negatively impact interactions with pedestrians because of the changing status of the drivers. With control transferred to automation, pedestrians will not be able to rely on cues from driver behaviours anymore. This could lead to misinterpretation of an AV's intention and increase the risk of critical conflict. In their study, Malmsten Lundgren *et al.* suggested that the introduction of AV in the urban context mays lead to a notable change in how pedestrians experience AV compared to conventional vehicles (Malmsten Lundgren *et al.*, 2016). Pedestrians rated eye contact with a driver as promoting safe interaction; whereas apparent driver distraction in AV (e.g., phoning or reading the newspaper) increased stress for the pedestrians and was associated with an unpleasant interaction. Moreover, beyond the stress experienced, a new set of road safety issues also arise according to the behavioural difference between automated versus conventional vehicles piloted by real humans, more specifically for older people (Dommès et al., 2021). In this general context, our main research questions are the followed: How pedestrians will assess the safety of AVs' behaviour to yield before road crossing? Which kind of braking strategy will be assessed as safe or not, according to car decelerating and distances to stop? Will be these safety assessments similar when the participant will experience the interaction as a pedestrian, or as an AV passenger? Finally, how elderly people will perceive and assess the safety of AV's behaviours to yield compared to a group of young participants?

2.Method

Because automated cars are not currently traveling on public roads, the main way to study this issue require to use immersive simulation tools to allow real humans to « practically experience » (even if in a virtual way) future interactions with such automated vehicles (Kyriakidis et al., 2019). In order to study how interactions between pedestrians and automated vehicles may look like in the future, and how road safety may be potentially affected by the AV behaviour, such an immersive experiment was implemented in the SUaaVE H2020 European project (*SUpporting acceptance of automated VEhicle*). In this aim, a set of driving scenarios was developed thanks to a *Virtual Human-Centred Design* platform of the University Gustave Eiffel (i.e. the *V-HCD*; Bellet *et al.*, 2019). Figure 1 presents the urban environment developed with Unreal graphical Engine 4 in the V-HCD for this experiment, at the moment of the driving scenario where the pedestrian is willing to cross the street while the AV is approaching.

FIGURE 1: PEDESTRIAN AND AUTOMATED VEHICLE SCENARIO OF INTERACTION

To allow participants to experience immersive interactions with automated vehicles, both on-board and outside of the AV, a dual-phases experiment of road-crossing situations was designed: one focused on the pedestrian's perspective, and the other from the AV passenger's point of view.

2.1 From the Pedestrian point of view

To support the experiment from the pedestrian's point of view, a virtual reality (VR) head-mounted display VIVE™ Pro Eye was used to simulate a realistic environment thanks to a resolution of 1440x4600 pixels per eye, a field of view of 110 degrees, and a refresh rate of 90 Hz. Contrary to experiments conducted under real-world conditions, VR offers major advantages in safety, reproducibility and experimental control.

Figure 2 (right view) shows the road environment as perceived by the participant as a pedestrian. This part of the experiment focus on assessment about the safety of AV breaking behaviour when approaching, without effectively implementing the crossing behaviour. Participants are located on the pavement facing a continuous flow of approaching vehicles. First, a randomised number of conventional vehicles not stop, and then a AV is approaching and stop according to eight different braking strategies (i.e., four distinct braking approaches and at two different stopping distances). Participants have to randomly experience these eight scenarios and to assess the safety of each one of these AV yielding behaviours, when they would like to cross the street in an urban area without zebra crossing.

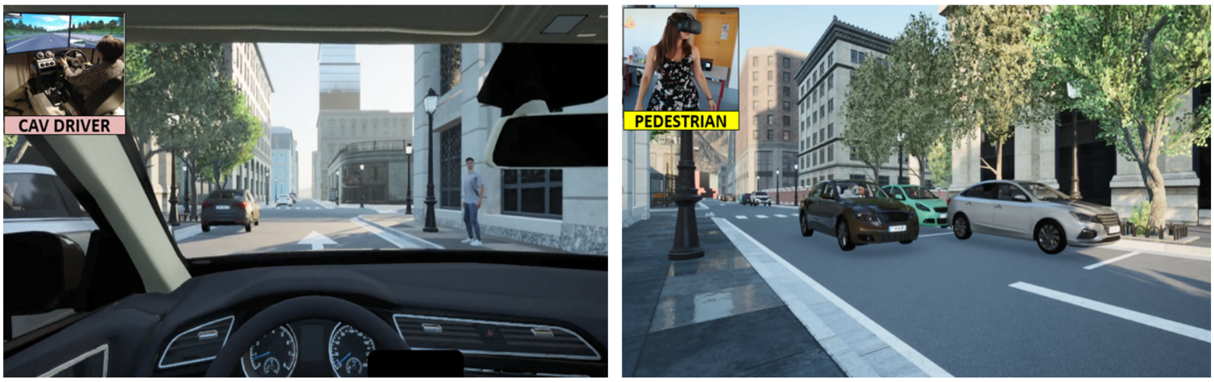

FIGURE 2: *THE SITUATION AS SEEN BY THE AV PASSENGER (LEFT) AND THE PEDESTRIAN (RIGHT)*

2.2 From the AV occupant's point of view

The part of the experiment involving an AV passenger was performed on the Gustave Eiffel University's dynamic simulator (i.e., Develter *"Pro Evolution"* cabin) to support controlled examination of interactions with simulated pedestrians. Even if the dynamics of this simulator is limited (i.e., based on four small cylinders), it is possible to simulate different levels of braking. Figure 2 (left view) presents the road scene as seen from the AV driver point of view. During this part of the experiment, like for the previous one, participants experienced randomly eight AV braking strategies when yielding to a pedestrian. During these scenarios, the behaviour of the AV interacting with the (virtual) pedestrian was fully managed by vehicle automation.

2.3 AV yielding behaviours

A total of sixteen driving scenarios were presented to the participants for each modality, i.e. eight as a pedestrian and eight as an AV passenger. Among these scenarios, eight different braking strategies (i.e., in terms of car dynamics) and stopping distances were considered, as illustrated in Figure 3.

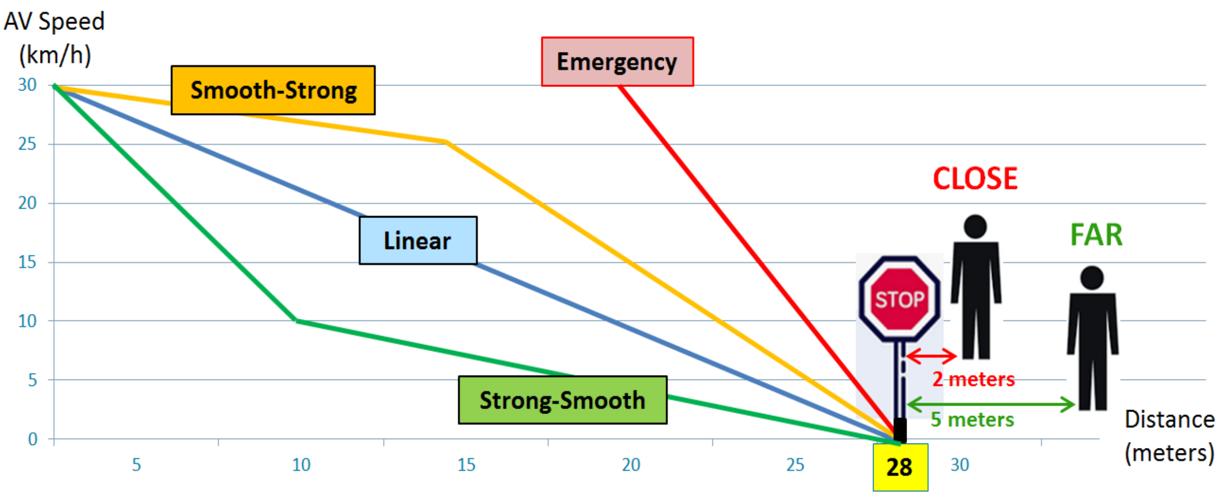

FIGURE 3: THE FOUR BRAKING STRATEGIES OF THE AUTOMATED VEHICLE

The four AV manoeuvres to yield are: "***Linear"*** deceleration (i.e., braking linearly on a distance of 28 meters), "***Strong-Smooth"*** (i.e., a strong braking followed by a smooth deceleration; this strategy could facilitate the detection of the beginning of the AV braking manoeuvre by pedestrians), "***Smooth-Strong"*** (i.e., a smooth followed by a strong deceleration; this strategy could be more gradually and comfortable for the AV passenger). These three strategies were inspired from real drivers' behaviours to yield observed in naturalistic traffic conditions in a 30 km/h urban area (Schneeman and Gohl, 2016). Conversely, the last yielding behaviour, i.e. "***Emergency"***, is automation-inspired and simulates the reaction of an Automated Emergency Braking system (AEB) when facing a dangerous crossing decision of a pedestrian (i.e., very strong linear braking on a very short distance of 8 meters, corresponding to the maximum braking power of a real car). These four yielding behaviours are associated with two alternative stopping distances: "***Far***" (distance of 5 meters from the pedestrian) and "***Close***" (distance of 2 meters).

After each scenario, the participant (as a pedestrian or as an AV passenger) will be asked to assess the safety of the AV behaviour to yield, using a continuous scale ranging from 0 (i.e., "*totally unsafe*") to 100 (i.e., "*totally safe*"). The motivation for using such a 0-100 Likert scales in this experiment (against 5 or 7-levels Likert scales, more commonly used in social sciences) was to collect individual assessments formulated through continuous numerical values, the latter being required in order to support quantitative statistical analyses based on parametric tests, like ANOVA or t-tests (Chimi and Russell, 2009; Yusoff and Mohd Janor, 2014 ; Bellet *et al.*, 2018).

2.4 Participants

Forty participants were involved in this experiment: 20 young drivers (10 males and 10 females, mean age of 25.1 years old, S.D. 4.1 years) and 20 elderly drivers (10 males and 10 females, mean age of 67.5 years old, S.D. 4.5 years). Half of them started with the pedestrian's experiment and continued with the AV occupant's point of view, while the other half done the contrary. All the participants had a valid driving license and drive a car regularly.

2.5 Main hypotheses

Per hypothesis, it is expected that among the eight braking strategies performed by the AVs' to give the way to the pedestrian, some of them should be assessed as less safe than the others, more particularly from the pedestrian point of view.

Typically, a far stopping distance of 5 meters should be evaluated as more safe for pedestrians than a shortest distance of 2 meters.

Moreover, the AEB behaviour was designed as an emergency reaction that is not really suitable to the scenarios studied in this experiment (i.e., AV approaching to a pedestrian who is quietly waiting to cross on the pavement). Thus, because of their critical nature and their inappropriateness for our scenarios, these AEB behaviours should be perceived as being less safe than the six other AV yielding manoeuvres (whether associated with a Far or a Close stopping distance).

Finally, regarding the age of the participants, literature has shown that older people may have more difficulties than younger pedestrians to identify time gap and make a safe decision to cross, more particularly in the frame of complex traffic situations and unfamiliar infrastructures, or when facing a dense continuous flow of approaching vehicles (Lobjois and Cavallo, 2007; Schmidt and Färber, 2009; Dommès, 2019; Núñez Velasco et al., 2019). The speed of the approaching vehicles was also identified as particularly important risk factor for elderly pedestrians, that they should adequately estimate them before implementing their road-crossing decision (Cavallo et al., 2009; Beggiato et al., 2017). At this level, the aim of this experiment will be to study if they will perceive and assess the safety of the different AV's yielding behaviours in the same way than youngest participants, or alternatively, if they have specific age-related difficulties in this evaluation task.

3.Results

3.1 Safety assessment of the AV behaviour according to the stopping distance

Figure 4 presents participants' safety assessments related to the AV yielding behaviours when they experienced the interaction as pedestrians (on the left) or as AV passengers (on the right). In accordance with our initial hypotheses, both old and young participants perceive the *Far* stopping distance as safer as pedestrians. Similar results are also found as AV passengers. These results are not surprising, because the more the stopping distance is far to the pedestrian, the more the safety margin is important, and the less the situation is perceived as being risked.

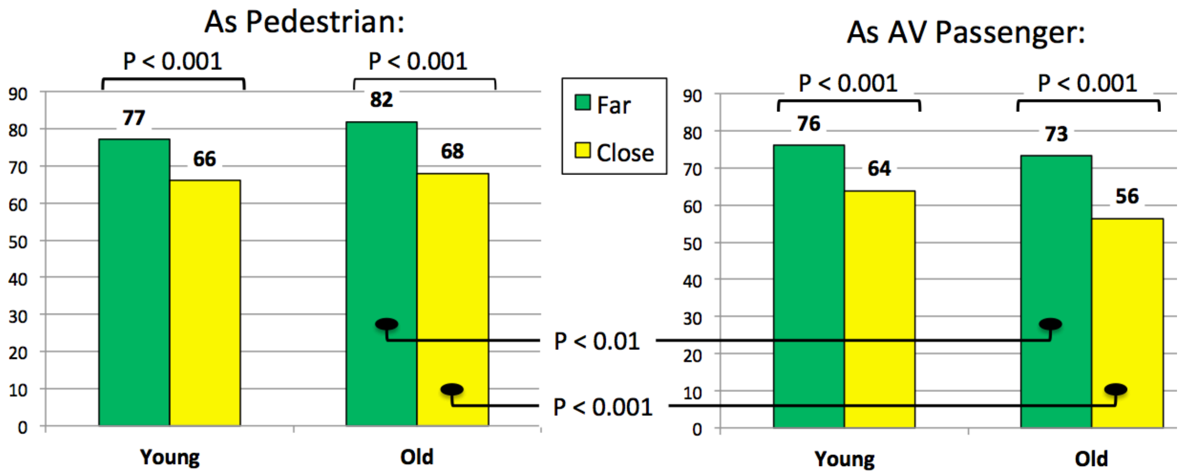

FIGURE 4: SAFETY ASSESSMENT OF THE AV BEHAVIOUR ACCORDING TO THE STOPPING DISTANCE

More interestingly, a significant difference is also found for the sample of older participants: their safety ratings about AV yielding behaviours are significantly higher (paired t-tests), for both Far and Close distances, when assessed from the pedestrian than from the AV passenger point of view. This result indicates that elderly people have not the same way to perceive and assess the safety of AV yielding behaviours from "the inside" and from "the outside" of the car: as a pedestrian, they assess them significantly safer than as a passenger. Conversely, it is not the case for the young participants, who rate AV behaviours similarly, whether as pedestrians or as AV passengers.

3.2 Safety assessment of the AV braking manoeuvres to yield

As shown in Figure 5 (combining old and young participants' ratings), ANOVA and post-hoc LSD tests indicate significant differences between four main blocks of AV braking behaviours in terms of safety assessment, both as pedestrian and as AV passenger.

As initially assumed, the Far stopping distance associated with Linear, Strong-Smooth and Smooth-Strong deceleration is assessed as highly safe by all the participants (more than 80/100, corresponding to a high positive value; cf. Bellet et al., 2018).

At the other extremity of the string, AV Close Emergency braking is assessed as an unsafe behaviour to yield, especially from the AV passenger's point of view (31/100).

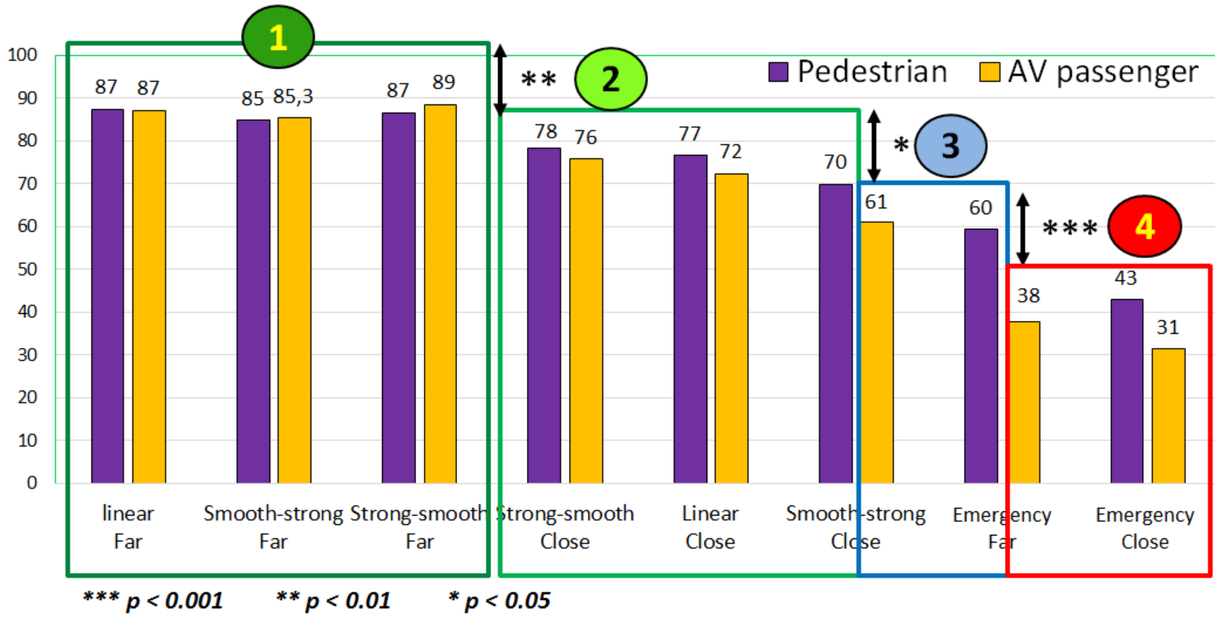

FIGURE 5: PARTICIPANTS' EVALUATIONS (ALL GROUPS) ABOUT THE DIFFERENT AV YIELDING BEHAVIOURS, FROM THE PEDESTRIAN VERSUS THE AV PASSENGER POINT OF VIEW

3.3 Perceived safety of AV yielding behaviours according to participants' age

Despite these global similarities between all the participants in terms of AV behaviours safety assessment, some statistical differences appear between old and young groups (paired t-tests; significance values directly presented in Figure 6 and 7).

As AV passengers (Figure 6), two AV braking strategies were assessed as significantly less safe by old participants compared to young's ratings: (1) **Linear close** (mean score of 80 for young participants [*S.D.* = 16.2] against 64.5 for old [*S.D.* = 27.2]), **Emergency Far** (mean score of 44.2 [*S.D.* = 21.8] for young participants against 31.2 for old [*S.D.* = 23.3]).

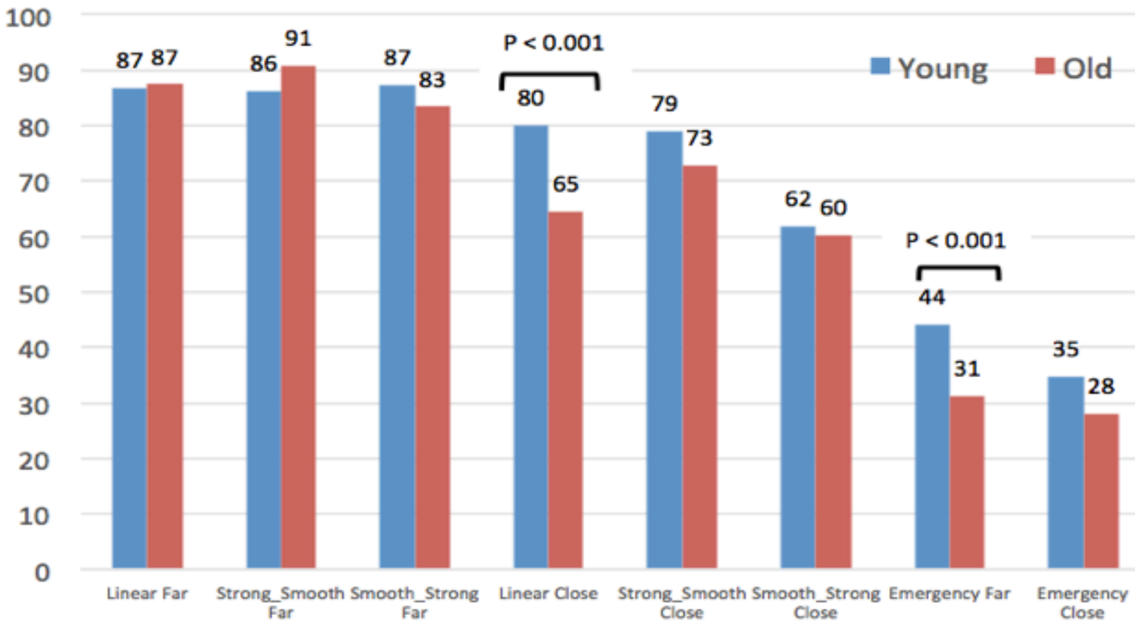

FIGURE 6: EVALUATION OF AV BRAKING STRATEGIES SAFETY AS A AV PASSENGERS

Conversely (Figure 11), as pedestrians, old participants assess the AEB Emergency braking as significantly safer than young participants. This result seems surprising, according to their higher vulnerability in case of accident. It is the case for *Emergency Close*, but also in a more impressive way for the *Emergency Far* yielding behaviour, which is assessed as very safe by elderly people (67/100), against neutral by young participants (51/100).

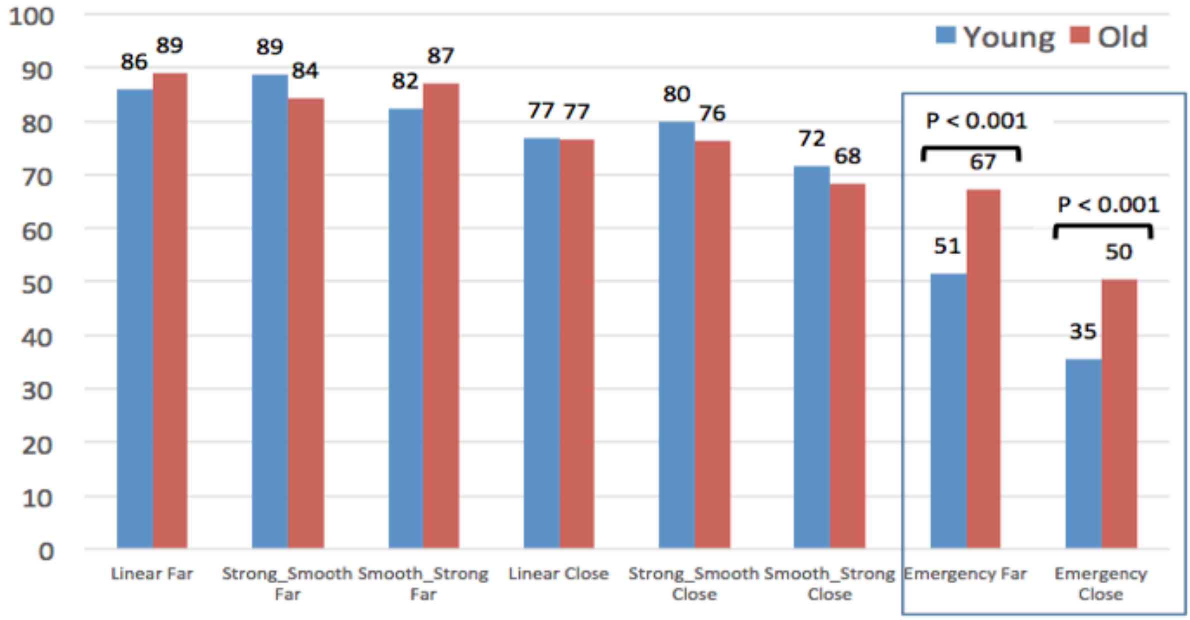

FIGURE 7: EVALUATION OF AV BRAKING STRATEGIES SAFETY, AS A PEDESTRIAN

Finally, when jointly considering results of figures 6 and 7, differences between old and young participants are highly contrasted: Although young participants provide quite similar judgements from the Pedestrian and the AV Passenger's point of views, older participants' ratings are totally different regarding the 2 Emergency braking (difference of 36 points for Emergency Far, and of 22 points for Emergency Close). As pedestrians, it seems that elderly participants have difficulties to visually perceive and evaluate the abruptness of the AEB deceleration, which is not the case when they experience the same AEB yielding behaviours on-board the AV.

4.Discussion

The present study aimed at examining the judgments of two groups of participants (young and old) when facing 8 AV braking strategies to yield a pedestrian. All these braking strategies were experienced two times by each participant (as a "Pedestrian" and then as an "AV Passenger" for 50% of them, versus alternatively as an "AV Passenger" and then as a "Pedestrian", for the others).

At a general level, our main initial hypotheses are validated in the sense that "Far" stopping distances of 5 meters (in front of the pedestrian) were assessed by all the participants as significantly safer than "Close" stopping distances of 2 meters. Moreover, a common hierarchy of the safety of the different braking manoeuvers was shared by all the participants (presented in figure 5), ranging from the one side to Far Linear, Strong-Smooth and Smooth-Strong behaviours (assessed as highly safe) and, from the over side, to Emergency braking strategies (assessed as less safe, whether associated with a Far and or a Close stopping distance).

However, a set of additional results was obtained regarding the group of elderly participants, more specifically for the yielding behaviours based on an Emergency braking. Such emergency braking was designed to simulate the reaction of an AEB system facing a dangerous pedestrian's behaviour, that is not really suitable to the scenarios studied in this experiment (i.e., AV approaching to a pedestrian who is quietly waiting to cross on the pavement). Thus, because of their critical nature and their inappropriateness in this experiment, these yielding behaviours should be perceived as less safe than the other AV yielding manoeuvres. Per hypothesis, we thus expected a negative judgment from our participants about these AEB yielding behaviours, whether associated with a Far or a Close stopping distance.

This hypothesis is effectively confirmed for the group of young participants, providing safety ratings of 51.4 and 44.4/100 for the Emergency braking with a Far distance (as pedestrian and as AV passenger, respectively), and of 35.4 (as pedestrian) and 34.7/100 (as AV passenger) for the Emergency braking with a Close stopping distance.

Conversely, results obtained for the old participants are more contrasted. Compared to the youngest, their evaluations as AV passengers are in line with our initial hypothesis predicting an unsafe assessment of such Emergency braking (i.e., rating of 31.2/100 for the Far distance and of 28.1 for the Close stopping). However, and by contrast, it is absolutely not the case when they had to assess the safety of AEB behaviours as pedestrians: for the Close stopping distance, the emergency braking was neutrally evaluated (I.e., 50.5 on the 0-100 Likert scale) and, more critical, their judgement were highly positive (with a safety rating of 67.1/100) towards AEB yielding behaviour coupled with a Far stopping distance, which is not a relevant AV behaviour to give the way to a pedestrian who is waiting a gap to cross on the pavement in a non protected area (and why implementing the maximum braking power of the vehicle, if it is at last to stop the car at 5 meters from the obstacle?).

These results confirm the literature about the difficulties experienced by older people to perceive and assess risks when they have to make a road-crossing decision. As pedestrians, it seems that our elderly participants have difficulty to visually evaluate the "brutal nature" of the AEB emergency braking deceleration. Conversely, when on-board the AV as a passenger, they seem more aware about the inappropriateness of such AEB emergency braking, in order to yield a pedestrian.

This last result is in line with the literature, showing that older pedestrians may have more difficulties than younger people to adequately perceive speeds and distances of approaching vehicles, to identify safe time gap, and then make a safe road-crossing decision, more particularly when are facing to dense traffic with a continuous flow of approaching vehicles (Lobjois and Cavallo, 2007; Schmidt and Färber, 2009; Cavallo et al., 2009; Dommès, 2019; Núñez Velasco et al., 2019).

5.Conclusion

The experiment implemented in this study was designed to investigate the judgments of two groups of participants (50% females; 20 young mean-aged of 25.1 and 20 old mean-aged of 67.5 years) when experiencing different AV braking behaviour from two points of view: as a "Pedestrian" and as an "AV Passenger". Results obtained shown that AV braking strategies stopping the car at 5 meters of the pedestrians are significantly assessed as more safe than braking strategies stopping closer to them (i.e. 2 meters). Moreover, Emergency Braking strategies, simulating the reaction of an AEB system on the driving simulator, were assessed as less safe by all our participants than other yielding behaviours. Nevertheless, some significant differences appeared at this level between the two groups of participants. Compared to young people, who assessed the safety of the AV manoeuvres similarly (including AEB emergency braking), whether as a pedestrian or as an AV passenger, older participants had a tendency - as Pedestrian - to misperceived and/or misestimate the "velocity/brutality" and the inappropriateness of such AEB Braking manoeuver, at last in the frame of the driving scenarios implemented for this study. By contrast, such misperception effect disappeared when they took place on-board the dynamic AV simulator, indicating that this difficulty is more related to their visual perception than to their cognitive judgement. Of course, these results were obtained by using a Virtual Reality head-mounted display, and data collected in naturalistic conditions are required to confirm them. However, if validated, they may be of prior importance for future road safety when the VA will be introduced on the public road. Today, elderly people are particularly vulnerable road users (in France, elderly people of 75 years old and more represent 36% of killed pedestrians, while they represented 9% of the French population in 2018). If they effectively have more difficulties than other road users to perceive and assess adequately VA deceleration velocity, it should increase their risk when interacting with the VA. One possible solution to avoid this risk is in the future is to equip automated vehicles of an External HMI specially designed to support them in this type of interaction (Begiato et al., 2017). Such an E-HMI was developed by Eiffel University in the SUaaVE project and is currently in test to evaluate its potential benefits for all road users in general, and for elderly pedestrians in particular.

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