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Crosswalk time estimation and time perception: An experimental study among older female pedestrians

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ABSTRACT

Since the sense of time is strongly influenced by advancing age, this laboratory study aimed to find out more about older pedestrians' decisions to cross the road, focusing on their estimates of how long it would take them to cross. The walking times of older female adults with or without any walking impairment and of healthy young adults were recorded on a walkway representing a road section. Participants also performed actual and imagined crossings of this "road" as well as a duration production task. Results showed that misestimated crossing times were related to the individual time base, with stronger time distortions in some older participants. A comparison between the older participants with disabilities and their age-paired counterparts without disabilities revealed an overestimation of crossing time in the former, affording them a bigger safety margin.

1. Introduction

Successful aging is closely associated with mobility. Using transportation, driving and walking often call for temporal skills. As for pedestrians, properly judging whether or not a traffic gap is suitable is a key skill for safely crossing the road. It involves accurately estimating not only the speed of the incoming traffic but also one's own speed and crossing time. Crossing a road is a critical moment for older pedestrians, and it has been shown that they frequently try to cross in a duration that is too short (Oxley et al., 2005; Lobjois and Cavallo, 2007). A partial explanation for this error of judgment is that they tend to rely mostly on distance rather than vehicle speed cues when assessing whether or not it is safe to cross (Lobjois and Cavallo, 2007).

Another risk factor in this assessment process could be that older pedestrians underestimate how long they take to cross the road. Few studies to date have addressed this particular issue. Holland and Hill (2010) used a traffic simulator to try to pinpoint factors affecting road crossing choices and investigated crossing time estimates separately with a task where participants were asked to walk 7 m (corresponding to the width of the road in the simulation task) along a corridor. The actual crossing duration was compared to the duration of an imagined crossing (imagined duration), corresponding to the delay between the 'go' command given by the researcher and the 'now' signal given by participants upon reaching the arrival mark in their imagination. An age-related effect occurred independently of gender or driver status. People between the ages of 25 and 59 were the most accurate. People between the ages of 60 and 74 were most likely to underestimate their walking duration, whereas people over the age of 74 were most likely to over-estimate it. The authors considered these effects to result from the participants' failure to adapt sufficiently to impairments that contribute to slow walking speed, which could be neglected by the former and overestimated by the latter. Importantly, the discrepancy (squared difference between actual and imagined walking durations) was related to a higher percentage of unsafe crossings and a smaller safety margin in the simulation task. On real roads approximately 7 m wide, free of incoming traffic, Zivotofsky et al. (2012) also observed that able-bodied persons mostly in their 70 s underestimated their crossing duration, whereas younger controls were accurate. Smaller age-related effects were reported by Schott and Munzert (2007) and Schott (2012) who implemented an imagined crossing task that was performed with eyes closed, across distances ranging from 7 m to respectively 25 m or 40 m. The difference between actual and imagined crossing durations was small in participants under 70, regardless of the distance involved. Shorter estimates were provided by older participants, especially those aged 80, but for distances greater than usual road distances (more than 7 m). Since the imagined crossing was probably performed

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with their eyes open in the other studies, one tentative consideration could be that visual information (necessarily processed when crossing a road) may increase the inaccuracy of crossing duration estimates with advancing age.

An additional explanation for participants' performance as regards their crossing duration estimates may have to do with their sense of time, especially for durations intuitively expressed in seconds, i.e., that have to be processed in many everyday situations, including crossing the road; these durations are mostly studied with reference to the scalar timing theory (cf. Gibbon et al., 1984).[1] Underestimating the time needed to cross is potentially the more dangerous disturbance and may be related to the fact that time passes more quickly for older adults. In a review of 16 studies that examined durations ranging from 1.3 s to 480 s without concomitant non-temporal tasks, Block et al. (1998) concluded that some older adults actually produce shorter durations (by marking the beginning and end of an interval specified by the experimenter) and their verbal estimates (in time units) of a given duration are compatibly higher than those of younger adults (see also Coehlo et al., 2004). Explanations assumed a faster internal pacemaker in the older individuals, or overcompensation for a slower pacemaker.

However, there is also some support for the opposite idea, namely that time passes more slowly for some older people, and this could result in safer crossings. It has been reported that older adults' verbal duration estimates are sometimes shorter than those of young adults (e.g., Craik and Hay, 1999; Pouthas and Perbal, 2004), and their duration productions are longer, in the range of 5–120 s (e.g., Craik and Hay, 1999; Perbal et al., 2003; Pouthas and Perbal, 2004). They also have lower tapping rates in motor tempo tasks (Baudouin et al., 2004; Vanneste et al., 2001) seen as reflecting the pulse-emitting rate of the pacemaker (Baudouin et al., 2006a), which is therefore described as slower in older people and itself putatively related to an age-related decrease in body temperature or metabolism (Block et al., 1999). In addition, an age-related decline in attentional resources may influence the experienced time and prevent the pulses from entering the accumulator by closing the switch (Block and Zakay, 1997; Burle and Casini, 2001).

Since the time memory system (short-term working and reference memories) is a main component of the scalar timing theory, memory impairments have also been seen as a causal factor for increased time distortion in older people. Memory processes are mainly studied by requiring participants to reproduce a time sample (Baudouin et al., 2006a; Eisler and Eisler, 1994), but these reproduction tasks have been inconclusively related to aging (Carrasco et al., 2001; Baudouin et al., 2006a,b; Perbal et al., 2002; for negative findings, see Block et al., 1998).

The apparent contradiction between the two sets of findings relating to aging and time perception (overestimation or underestimation of time) may be linked to within-individual and between-individual influences, which may be stronger in older individuals. Inter-individual differences in time competence have been shown to depend on their state of health, quality of life and psychological functioning (e.g., Baum et al., 1984; Saint-Pierre and Dubé, 1993; Wallach and Green, 1961). Intra-individual differences may be related to the participants' current arousal state, but they may also have to do with procedural components that allow participants to allocate more or less attention to the time task (Block and Zakay, 1997). The latter is particularly relevant for crossing the road. However, an initial research step should relate performance in a classical laboratory time task aimed at assessing the sense of time with time performance for a road crossing task, both designed without any concurrent tasks in order to minimize cognitive load. The present study addressed this issue.

In the present study, older participants and younger controls performed two tasks in the context of a single, within-participant experimental session: (1) a duration production task and (2) a task aimed at comparing actual and imagined crossing durations, which was performed by participants with their eyes open in an impoverished artificial environment meant to represent a section of road. The expected results were (1) the occurrence of an age-related time distortion, (2) an age-related reduction of accuracy of crossing time estimates, with less accuracy for slower people, and (3) a link between the performances of these two tasks. After first collecting data with healthy participants, we added a group of older participants who all reported having a disease impairing their ability to walk. These participants were expected to underestimate their crossing duration more than age-paired healthy controls, due to a failure to adapt to the impairments that slowed their walking speed. Since imagined crossing duration could depend on the extent to which a person is able to generate a mental representation of movement, an ability that decreases with age (Mulder et al., 2007), participants in both experiments answered a kinesthetic and visual imagery questionnaire. Finally, as a subsidiary concern, we were also keen to examine (1) the time cost of negotiating/going up and down road curbs in an actual crossing and (2) whether such a time cost is taken into account in an imagined crossing. The crossing data were therefore collected with and without curbs.

2. Method

2.1. Participants

A total of 36 female participants between the ages of 63 and 91, and 12 younger females between the ages of 22 and 31 took part in the study. Only female volunteers were allowed to enroll since there were more women than men in our samples of older participants, i.e., essentially leisure groups in three northern French towns (La Bassée, Liévin, and Valenciennes). They were screened based on their answers to a health questionnaire. Twenty-four older participants were selected first and split into two age groups based on a median split, i.e., 64–73 years (young–old group) versus 74–91 years (old–old group), the cutting point being close to the one used by Holland and Hill (2010). These participants reported not having any particular walking disability, other than normal aging. By contrast, the remaining 12 older participants recruited in a second experimental phase reported suffering from hip or lower limb diseases impairing their ability to walk (disabled old group). Osteoarthritis was the most frequent diagnosis (9 participants). The other problems were essentially persistent after-effects of fractures caused by accidents or falls. Importantly, these disabled participants were included providing they kept up a walking activity in spite of their impairment. With respect to the counterbalancing, these disabled participants in the 63–78 age range (with only 2 over the age of 73) were paired as closely as possible for age with participants recruited during the first experimental phase, who were assigned a posteriori to a non-disabled old group constituted for comparative purposes. Members of these two groups had a similar body mass index, although the participants in the disabled group were taller ($F(1,22) = 4.62$, $p < 0.04$, partial $\eta^2 = 0.17$) and heavier ($F(1,22) = 4.93$, $p < 0.04$, partial $\eta^2 = 0.18$) than their counterparts. It was not possible to obtain better pairing within the constraints of the experimental schedule.

[1] At the first processing step (clock stage), a pacemaker produces pulses at a given rate and a switch controls the access of the pulses to an accumulator. The accumulator sums the pulses which increase in number as time elapses. After consulting a reference memory where durations have been stored in the past, a comparator may decide the appropriate temporal responses for the duration currently in working memory.

Table 1
Sample characteristics. Means (standard deviation) are shown for each group with a statistical decision (*p*-value) on differences between groups in the last columns for the two sets of comparisons: non-disabled groups (columns 2–5), disabled versus non-disabled old groups (columns 6–7) (*ns* = non-significant differences; BMI: Body Mass Index; KVIQ: Kinesthetic and Visual Imagery Questionnaire, maximum total score: 5).

	Young group	Young old group	Old old group	Between-group differences	Disabled old group	Control old group	Between-group differences
Age	26.17 (2.92)	67.58 (3.37)	81.92 (4.85)	$p < 0.01$	68.42 (4.66)	69.92 (5.57)	*ns*
Height (m)	1.61 (0.07)	1.69 (0.07)	1.56 (0.06)	*ns*	1.63 (0.06)	1.57 (0.07)	$p < 0.04$
Weight (kg)	57.75 (8.59)	66.08 (13.43)	64.08 (9.75)	*ns*	73.75 (12.95)	63.24 (10.03)	$p < 0.04$
BMI (kg/m^2)	22.14 (2.82)	25.95 (4.44)	26.14 (3.92)	$p < 0.02$	27.73 (4.33)	25.49 (3.36)	*ns*
Sight	9.33 (1.07)	8.67 (1.43)	7.33 (1.30)	$p < 0.01$	7.25 (1.54)	7.92 (1.68)	*ns*
KVIQ score	3.44 (0.61)	3.72 (0.92)	3.28 (0.61)	*ns*	3.77 (0.71)	3.53 (0.93)	*ns*

The younger participants making up the control group were recruited via convenience sampling among the researchers' acquaintances. Exclusion criteria in each case were neurological and cardiac diseases. Diabetic patients were also excluded because of a possible depletion of bodily sensitivity (e.g., Menz et al., 2004). Table 1 shows the main characteristics of the study groups. We used the Mini-Mental State Examination (MMSE, Folstein et al., 1975) to screen for cognitive dysfunction, and all participants scored above 26; i.e., two points above the threshold indicating cognitive dysfunctions that could herald dementia. Despite an unavoidable reduction in visual acuity with age (Table 1), all the participants' far visual acuity was within normal limits or corrected to within normal limits, as assessed by their binocular identification of varying sizes of letters of the alphabet (Optometric Monoyer chart viewed at 3 m).

2.2. Material

As shown in Fig. 1, a walkway was designed as a 1 m wide strip of thin black linoleum placed on the floor. Part of it represented a 7 m wide road section. Two wooden boxes (1 m × 1.20 m × 0.14 m) covered in thin carpet were used to represent the curbs. When required, they were placed on top of the strip of linoleum, at each end of the 7 m road section. Markings were added on the linoleum and on the boxes, 50 cm from the sides of the "road". The markings indicated participants' starting position at the beginning of each trial. The total length of the walkway was therefore 8 m.

An Ergo Timer Globus stopwatch linked up to photoelectric cells was used to measure the duration of the actual and imagined crossings with greater accuracy than a hand-held stopwatch. The Ergo Timer Globus stopwatch can be used in either go/come back mode or start/stop mode. Accordingly, there was no need for any unmeasured crossings between successive trials, since both ends could be used as the starting point. A home-made chronometer was used in the duration production task. A response box with a response button and LED ("on" during the produced duration) was connected to a control box with a screen on which the experimenter could see the duration produced.

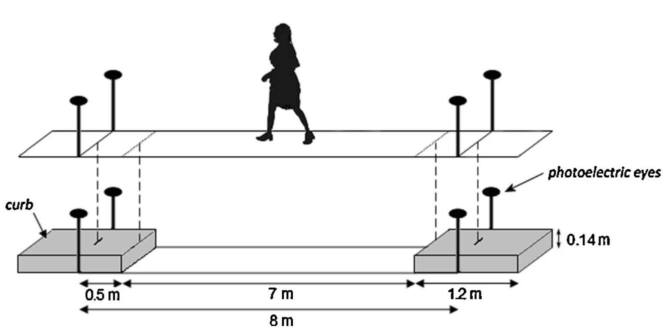

Fig. 1. Diagram showing the experimental design, with a participant (no-curb condition: top; curb condition: bottom).

2.3. Questionnaires

The Kinesthetic and Visual Imagery Questionnaire (KVIQ-10; French validation, Malouin et al., 2007) was chosen because it involved no complex movements. This questionnaire is used to assess both the visual and kinaesthetic dimensions of motor imagery, rated on a five-point ordinal scale in terms of both the clarity of the image or the intensity of sensation. The total score is a general index of motor imagery skill.

A questionnaire about walking habits and experiences was designed for the experiment. Participants were asked to give a mark of between 0 and 10 for the following aspects relating to walking as a pedestrian: (1) importance for their autonomy; (2) experienced pleasure; (3) fear of accidents; and (4) fear of falls. Likert scales were also used to assess the frequency with which participants walked in their everyday life (response modalities: less than once a month, 2 or 3 times a month, once a week, 2 or 3 times a week, at least once a day) and the mean duration of their walks (response modalities: <10 min, between 10 and 20 min, about 30 min, about an hour, more than an hour). Older participants were also invited to compare their present walking ability with how they walked when they were in their 20 s; their responses were given on a Likert scale (much better, better, same, worse, much worse), and converted into number coding (ranging from 2 to −2 values).

2.4. Procedure

The experiment was conducted in accordance with the Helsinki Declaration. Participants were initially contacted through information disseminated within a number of community groups. Older volunteers were met individually before the experimental session. On that occasion, they were given more explanations about the experiment and filled in the health questionnaire and MMSE. The experiment itself was performed in a large room usually used for sport or other recreational activities. Upon their arrival, participants answered questions designed to check for current problems that could abnormally impair their wellbeing (no positive answers were received), and they all gave their informed consent in writing. They then completed the questionnaire about their walking habits and experiences. We then checked their eye-sight, weighed them, and measured their height.

After that, participants performed the "crossing the road" task. At the start of each trial, participants had to stand on a mark just behind a stopwatch cell, either at floor level or on the 'curb'. In the actual walking trials, they were told to "cross the road" at their usual pace, as if they were in a natural setting in the absence of any traffic (actual crossing trials). The stopwatch was started as soon as they crossed the beam just in front of them and stopped as soon as they crossed the second beam on the opposite side (Fig. 1). In the imagined crossing trials, participants stood still on the marking with their eyes open and had to imagine they "were crossing the road" at their own pace. They started and stopped the stopwatch by passing their hand twice through the beam in front of them, once when they imagined themselves beginning to walk and once when they imagined they were passing between the cells on the opposite side of the road. There were 8 experimental trials, with each basic condition being completed twice. Half of the participants in each group began with the 'no-curb' condition and the other half with the 'curb' condition. During each of these curb conditions, actual and imagined crossings were alternated, with the order reversed for half of the participants in each subgroup. Participants initially took part in practice trials, with the 'curbs' placed 5 m apart, and actual walk training preceding imagined walk training.

The duration production task was proposed between the two sets of four experimental trials of the "crossing the road" task, in other words once the first environmental condition had been completed. The participants were seated at a table and had to produce durations of 5 s, 10 s, 20 s and 30 s once only and in counterbalanced order within each group. Each trial began as soon as the red LED on the response box was switched on, and participants had to press the button on this box when they estimated that the duration they were supposed to produce had elapsed. The KVIQ was performed just after the duration production task. No feedback was given on performance. A full session took approximately 45 min to complete.

2.5. Data analysis

We used the Statistica 8.0 package[2] to carry out the statistical analyses. When there was a breach of normality conditions and/or variance/covariance heterogeneity, a log transform was carried out. When the transformation proved to be insufficient to meet the requirements of parametric analyses, a non-parametric analysis, i.e., Wilcoxon T test, was performed. To avoid any trivial "time to be produced" effect, raw time production data were reduced to relative performances, such that negative values correspond to produced durations that were shorter than the requested duration. This procedure meant it was possible to compute a mean accuracy score for each participant, hereafter referred to as duration production (DP) accuracy. Accuracy of the crossing duration estimates, i.e., the difference between the actual and imagined crossing durations was also computed, and hereafter referred to as short crossing duration (CD) accuracy. We applied repeated measures ANOVAs according to the General Linear Model (GLM). Whenever necessary, we used planned comparisons (contrast analyses) to specify which pattern of means could explain the current effects. Attention was paid to effect size estimates (partial η^2). Links between variables were investigated by means of product–moment correlations and multiple regressions.

3. Results

3.1. Comparisons of the non-disabled groups

3.1.1. Time production

Regarding duration production, a 3 × 4 (Group × Duration) ANOVA performed on relative performance revealed a main effect of Group ($F(2,33) = 4.42$, $p < 0.02$, partial $\eta^2 = 0.21$), owing to an opposition between the young group and the two older groups ($F(1,33) = 8.82$, $p < 0.01$, partial $\eta^2 = 0.21$), since the two older groups did not significantly differ from each other ($F(1,33) < 1$, *ns*). There was also a significant Group × Duration interaction ($F(6,99) = 4.21$, $p < 0.01$, partial $\eta^2 = 0.20$; Fig. 3). There were no significant differences between the groups in respect of the 5 s production ($F(2,33) < 1$, *ns*). Concerning the other durations, and compared to the older participants, who under-produced them, the younger participants' productions were closer to the requested durations, and between-group comparisons increased along with the duration.

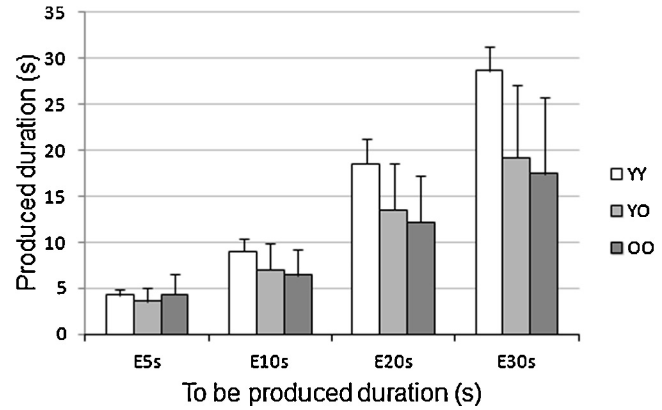

Fig. 2. Performance in the duration production task (mean and standard deviation), as a function of the requested duration and age group (YY: young–young group; YO: young–old group; OO: old–old group).

3.1.2. Walking self-report and crossing time

The statistics failed to show any differences between the three groups of the walking non-disabled participants for any of the questions about walking habits and experiences, although participants in the two old groups reported a decline in their walking ability since they were in their 20 s (overall mean: −0.54, $T(23) = -3.68$, $p < 0.01$, partial $\eta^2 = 0.37$).

Regarding actual crossing duration (log transformed), the 3 × 2 (Group × Curb) ANOVA revealed a main effect of Group ($F(2,33) = 7.83$, $p < 0.01$, partial $\eta^2 = 0.33$): crossing duration was shorter in the young group than in the two older groups ($F(1,33) = 15.65$, $p < 0.01$, partial $\eta^2 = 0.32$), which did not differ from each other ($F(1,33) < 1$, *ns*), with respective speeds of 1.32, 1.07, and 1.06 m/s. The main comparison between the curb and no-curb conditions reached significance, with an average crossing duration of 0.27 s longer in the curb condition ($F(1,33) = 8.94$, $p < 0.01$, partial $\eta^2 = 0.21$). The Age × Curb interaction was not significant ($F(2,33) = 2.00$, $p = 0.15$, partial $\eta^2 = 0.11$), but when contrast analyses were used to investigate the curb effect, significance was reached only in the old-old group ($F(1,33) = 10.52$, $p < 0.01$, partial $\eta^2 = 0.24$; mean difference: 0.49 s) (see Fig. 2).

3.1.3. Imagined crossing duration

The group factor was investigated using a non-parametric ANOVA, and did not reach significance ($H(2, N = 36) = 4.45$, $p = 0.11$).

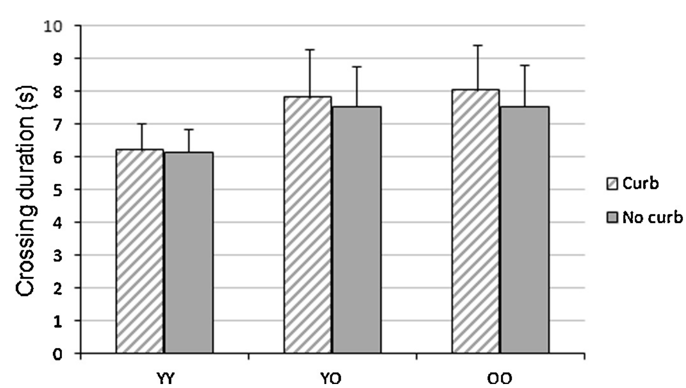

Fig. 3. Actual crossing duration (mean and standard deviation) on the 8 m walkway, with and without curbs in the three age groups (YY: young–young group; YO: young–old group; OO: old–old group).

[2] StatSoft, inc. (2007). STATISTICA (data analysis software system), version 8.0. www.statsoft.com.

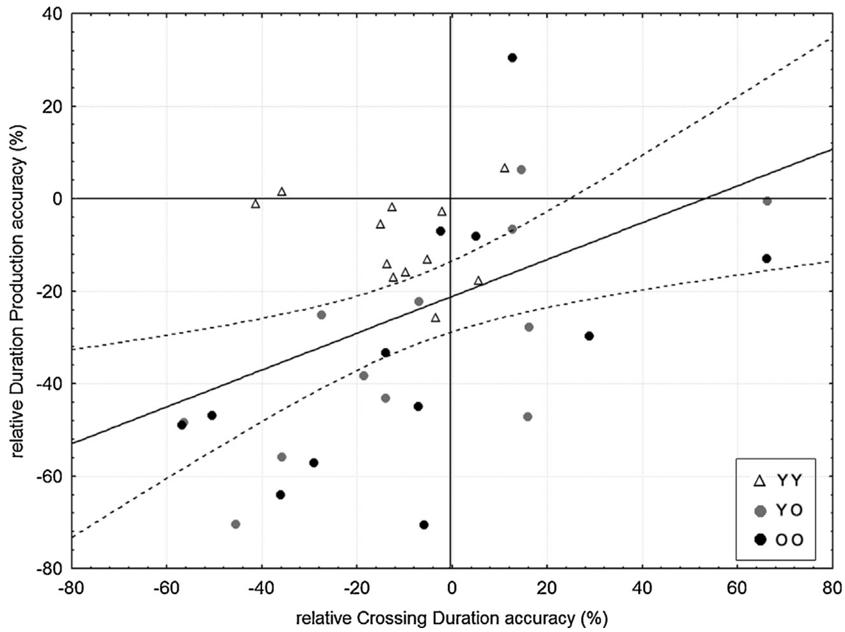

Fig. 4. Relative crossing duration accuracy (relative difference between the actual crossing duration and the imagined crossing duration, as a percentage) as a function of relative Duration production accuracy, for the young–young (YY), young–old (YO) and old–old (OO) participants.

In the imagined crossing condition, the difference between the curb and no-curb conditions no longer attained statistical significance ($T(36) = 321$, $p = 0.85$).

3.1.4. *Crossing duration accuracy*

Owing to the large increase in variances in the imagined crossing durations as opposed to the actual crossing durations (both log transformed, Box *M* test: $\chi^2(20) = 38.46$, $p < 0.01$), they were compared with non-parametric statistics. The imagined crossing durations were shorter than the actual crossing durations ($T(36) = 30.56$, $p < 0.05$).

As for the crossing duration (CD) accuracy, no significant effects resulted from the 3 × 2 (Group × Curb) ANOVA. The mean CD accuracy score was not significantly correlated with the actual crossing duration, irrespective of whether the correlation coefficient was calculated with or without the young group ($r = -0.06$, *ns*, in both cases), suggesting that people did not become less accurate when they became slower. In contrast, there was a significant correlation between the mean CD accuracy score and the mean duration production (DP) accuracy score, whether the correlation coefficient was calculated with or without the young group ($r(36) = 0.46$, and $r(24) = 0.63$, $p < 0.01$). Those who underestimated their crossing time more were generally those who produced the shorter durations at the duration production task (see Fig. 4). A multiple regression analysis was performed to try to find an explanation for the discrepancies between imagined and actual crossing durations in terms of potential predictors such as age, performance in time production, BMI, eyesight, fear of falling, perceived decline in walking ability, etc. The results of the analysis with forward and backward stepwise regression models confirmed that mean accuracy scores in time production ($F(1,33) = 16.68$, $p < 0.001$, partial $\eta^2 = 0.33$) and age ($F(1,33) = 6.20$, $p < 0.012$, partial $\eta^2 = 0.16$) were the two effective predictors. As shown in Fig. 4, both CD and DP accuracy scores in the young group were generally satisfactory (performance for the most part close to the origin), whereas the older participants showed a propensity to underestimate (performance mostly located in the lower left quadrant) despite huge inter-individual differences in these groups.

3.2. *Comparisons between the walking disabled and non-disabled old groups*

It is worth recalling Table 1, which showed there were no significant differences between the walking disabled group and the control group in terms of their characteristics, apart from their height and weight. The two groups did not differ in terms of their performance in the duration production task (regardless of the requested duration: $F(1,22) < 1$, *ns*). In line with the results set out above, all the participants produced shorter durations than the ones requested (about 36.6%: $F(1,22) = 80.67$, $p < 0.01$, partial $\eta^2 = 0.78$). There were no significant between-group differences in the KVIQ scores (cf. Table 1). In accordance with the selection criteria, the participants in the disabled old group indicated they walked less frequently than their counterparts ($F(1,22) = 4.77$, $p < 0.04$, partial $\eta^2 = 0.18$) and also reported a comparatively greater decline in their walking ability since they were in their 20 s (means: −1.33 (SD = 0.49) versus −0.42 (SD = 0.51), $F(1,22) = 19.87$, $p < 0.001$, partial $\eta^2 = 0.47$). No other significant differences emerged between the two groups as regards the other items covered by the questionnaire. During the experiment itself, the duration of their effective experimental crosswalks did not differ, whether they crossed with or without curbs (all $T(22) < 1$, *ns*; with a mean speed of 1.08 m/s).

After log transforming the actual and imagined crossing durations, the homogeneity of variance–covariance matrix assumption was satisfactory (Box *M* test: $\chi^2(10) = 11.48$, $p > 0.30$). Therefore, it was possible to analyze these data into a single 2 × 2 × 2 (Group × Crossing condition × Curb) ANOVA, with Crossing condition referring to the actual and imagined crossings. The potential effect of covariates such as weight and height was checked beforehand with a MANCOVA which showed that the Group × Height and Group × Weight interactions were not significant. The ANOVA revealed a significant difference between groups ($F(1,22) = 5.01$, $p < 0.03$, partial $\eta^2 = 0.18$), mainly due to the interaction with the Crossing condition ($F(1,22) = 20.43$, $p < 0.001$, partial $\eta^2 = 0.48$, Fig. 5), insofar as the imagined crossing durations of the disabled participants (overestimators) were longer than those of their counterparts (underestimators), whatever the curb condition ($F(1,22) < 1$, *ns*). The inclusion of age as a covariate in an ANCOVA

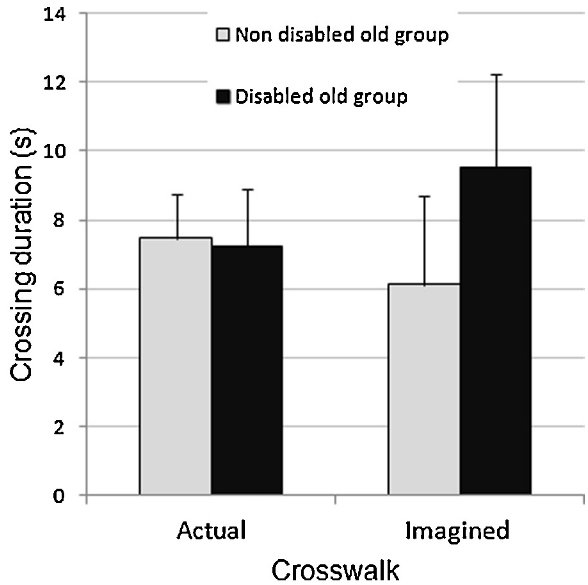

Fig. 5. Actual and imagined crossing durations (mean and standard deviation) for the walking disabled and non-disabled older participants.

did not eliminate this interaction and the main effect of age was non-significant.

4. Discussion

The present research study tested the idea that some older pedestrians may be at risk when crossing the road because they underestimate the time it takes them to cross as a result of (1) their failure to adapt to the reduction in their walking speed and/or (2) the acceleration of their subjective time. An acceleration of subjective time was observed, which is a finding that is consistent with previous findings relating to time psychology (Block et al., 1998; Coehlo et al., 2004). The older participants produced shorter empty durations than those who were younger. Overall, the 5 s duration appears less discriminative, possibly because it is closer to the lower limit of the temporal processing system (3 s, with great inter-individual variability according to Pöppel, 1997). Thus, in some individuals, it may involve different neural mechanisms than the longer durations. However, it is important to stress that for many of the older participants, their crossing duration was closer to 10 s or longer, with the present study confirming the well-identified slowing of walking pace with advancing years. Expressed in terms of walking speed, the mean values are similar to those recorded elsewhere (i.e., about 1.30 m/s for the younger participants, and closer to 1 m/s or less for the older participants; e.g., Romero-Ortuno et al., 2010). The greater data dispersion in the older groups also confirmed that older people are not a homogeneous population when it comes to walking speed.

The results did not support the idea that a failure to adapt sufficiently to the slowing of their walking pace might cause the older pedestrians to underestimate their crossing time in their go/no go decision-making process and consequently undertake hazardous crossings (Holland and Hill, 2010). First, among the participants without any disabling disease for walking, those with the slower walking speed were not those who underestimated their crossing time most. Second, the older participants suffering from hip or lower limb diseases over-rather than underestimated their crossing time. The latter effect warrants further discussion since the walking speed of the disabled participants during the experiment proved to be similar to that of their non-disabled counterparts. It is possible their walking speed is not the walking parameter most impacted by their disease (for such a conclusion in the case of osteoarthritis, see cf. Bejek et al., 2006). Nevertheless, all the disabled participants in the present experiment reported walking difficulties that could cause them to walk more slowly: limping, stiffness, cramps, and/or pain, but such difficulties should be mostly episodic. It is possible to assume these difficulties with walking were taken into account in the disabled participants' imagined walk, producing a wider safety margin. This could be consistent with Harrell (1990, 1991), who illustrated that, contrary to the stereotyped portrayal of the older people as less aware of the danger because of their diminished cognitive abilities, older pedestrians were in fact the safest age group (see also Granié et al., 2013). However, prudence with regards to this conclusion is necessary, especially for the present study, since our results were obtained for a small sample of older participants with a good vitality status. A faster walking speed for our participants in the old–old group as compared to those included in the experiment by Holland and Hill (2010) sustain this idea, but Zivotofsky et al. (2012) also observed an underestimation of crossing duration, with participants in their 70 s who walked rather slowly.

From the point of view of hierarchical risk models, which distinguish strategic, tactical and operational processing (Rasmussen, 1983; Michon, 1985), choosing the suitable time to cross refers to tactical adjustments (Tom et al., 2007). Safely estimating crossing time is therefore an element of the tactical strategy, into which disabled old participants may factor in the intrinsic risk of potentially experiencing walking difficulties. However, the question of whether overestimating crossing time in this way reflects a deliberate safety-driven adjustment or is purely a by-product of emotional processing (e.g., fear of pain) remains unanswered. No firm conclusion can be drawn from the failure to establish a link between overestimating crossing time and the anxiety-related items of the questionnaire in our sample. More information on that point should help to establish which theoretical risk model (initially developed to conceptualize drivers' risky behavior) is a better explanation for the pedestrians' estimates. With that aim in mind, the question of the role played by emotions and consciousness is crucial. The zero-risk theory developed by Näätänen and Summala (1974) postulated that individuals tend to evade or avoid the experience of risk, which is perceived as unpleasant. Fuller (1984) shared this view but without reference to a deliberate decision-making process. In contrast, the risk homeostasis theory developed by Wilde (1982) was based on a rational cost-benefit assessment. Further research should thus not only include a biomechanical analysis of the participants' gait, but also investigate more thoroughly the emotions felt by the older pedestrians when crossing a road. A different but compatible explanation could be that the participants suffering from a disease tended to imagine a disabled walk, and not a non-disabled one, since the interoceptive feedback provided by the former is perhaps greater. Since there were no between-group differences in the second experiment as regards performance in the time production task, the disabled older participants' overestimation of their crossing time cannot be explained with reference to their sense of time.

In contrast, the first experiment revealed that performance in the time production task predicted the crossing time estimate with a strong effect size, lending credence to the idea that a distorted sense of time contributes to hazardous crossing. Focusing on the sense of time appears more relevant than focusing on aging itself for identifying intrinsic risks relating to time perception. Further explanation of this time effect remains highly speculative. With reference to the internal clock models, either reliable overcompensation for a slowing of the pacemaker or increased pulse-emitting rate could fit the data for those who underestimated durations (i.e., both the duration to be produced and the crossing duration). However in light of the literature about the positive impact of arousal on the pulse-emitting rate, we cannot totally discard the idea that the present results could relate to the fact that the older participants were more aroused than the younger participants by taking part in the experiment. Arousal could therefore be seen as a factor for timing overcompensation of an initial slowing of the pulse-emitting rate. Considerable inter-individual differences in the impact of aging on time perception explained the entire spread of results, with some older participants having a performance deficit whereas others still performed as well as the youngest participants. Among aging populations, inter-individual differences in time competency have been shown to depend on health, quality of life and psychological functioning (e.g., Baum et al., 1984; Saint-Pierre and Dubé, 1993; Wallace and Green, 1961). Continued research involving applying the current procedure to a large sample of well-characterized older individuals would help toward developing a metric capable of identifying those who are at greater risk as regards crossing time estimates. Such an approach would require sufficient test/re-test reliability, another aspect to be tested.

Older pedestrians interviewed by Coffin and Morrall (1995) reported difficulty with negotiating curbs, but to the best of our knowledge, very few attempts have been made to quantify the time cost of curbs for older pedestrians (Knoblauch et al., 1999). We observed that the curbs led to longer crossing durations, an effect which tended to increase with age. For the participants in their mid-70 s and above, the curbs cost about half a second on average, with 25% of these participants taking more than a second longer to cross with curbs than without. The fact that the curb did not differentially affect the crossing duration of older pedestrians with or without a reported walking disability might be related to their not experiencing difficulties with walking during the experiment, as discussed above. The overall conclusion is that, for the older pedestrians, stepping on and off the curbs may affect the required crossing time, and not only increase the risk of falling. The attentional cost of these slower behavioral sequences warrants further investigation, bearing in mind that this experiment was performed in an impoverished environment. The aim will be to quantify the impact of traffic's attentional demands on the time cost of curbs. With regard to these aspects, this further research will no doubt take advantage of head pitch recordings as an indicator of more attention paid to walking (Avineri et al., 2012).

5. Study limitations

There are several potential limitations to the present investigation. There is a possibility that for several reasons older pedestrians sometimes pay less attention to their crossing time when crossing the road in everyday life than during the experiment. In particular, their willingness to perform well is probably weaker during their usual walk around their neighborhood than during the experiment, and they may also be less tired during the experiment since the overall walking distance was small. Besides, the experiment was conducted in an impoverished, artificial environment, which is therefore not representative of urban streets with traffic and a multitude of distractors. To test the influence of these factors, future experiments would need to try to establish a link between crossing time and time processing when there are distracting stimuli in the environment. A traffic simulator could be put to good use in such studies. Importantly also, when people had to cross a road, they did not allow the subjective duration to pass but their decision is based on a temporal perspective. However, the results obtained by Holland and Hill (2010) suggest a link exists between experimental chronometric walking performance and risks taken by older individuals, at least the male participants, when crossing a road. The fact that only females were recruited in the present experiment is thus another limitation, despite that gender differences in walking time estimation have not been reported previously (Holland and Hill, 2010; Schott, 2012).

6. Conclusion and recommendations

The present study illustrated the specific influence of the sense of time as a potential source of the risk taken by older pedestrians when crossing the road. It also showed that older pedestrians who suffer from diseases affecting their walking ability increased their temporal safety margin. This may be consistent with the idea that older pedestrians are very keen to reduce their risk-taking. Distortions in time perception could be more difficult for the older people to identify themselves than motor impairments. However, a duration production task is very easy to implement and, when strong distortions are revealed, these can be explained in a manner that is understandable and acceptable for most older people. It is therefore possible that they might take care to adjust their time estimates in the light of this new knowledge.

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