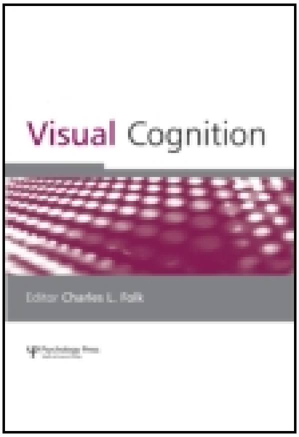

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Role of expertise and action in motion extrapolation from real road scenes

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Role of expertise and action in motion extrapolation from real road scenes

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The tendency of participants to "remember" the stopping point of an event as being farther along in the direction of motion has been a topic of study for about 30 years. The purpose of the present experiment was to test the influence of two factors on motion extrapolation: (1) The involvement of participants in the action, and (2) their expertise in the domain of automobile driving. Participants viewed real driving scenes from the driver's point of view. They were divided into four groups depending upon their involvement in the action (more or less active) and their driving experience (inexperienced or experienced). In order to get half of the participants involved in the driving situation, they had to use a steering wheel to follow the contour of the road. The results showed that both of these factors increased motion extrapolation. The discussion deals with how the interrelationships between real road scenes, expertise, and action-related knowledge affect motion extrapolation.

Keywords: Action involvement; Expertise; Motion extrapolation; Natural scene; Representational momentum.

Motion extrapolation usually refers to the tendency of participants to "remember" the stopping point of an event as being farther along in the direction of movement than it was in reality (Freyd & Finke, 1984). For about 30 years now, motion extrapolation has been studied in terms of

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representational momentum (RM), which is one of several variables that influence motion extrapolation. The RM effect has been demonstrated using a wide variety of materials, both with dynamic stimuli (e.g., a moving dot, a rotating rectangle, the continuous motion of a set of dots; for a detailed review, see Hubbard, 2005) and with static stimuli (drawings, photographs of actions; see Freyd, 1983; Freyd, Pantzer, & Cheng, 1988). Since the original work by Freyd and Finke (1984), a large body of research on representational momentum has shown that when the cognitive system is processing a dynamic event, it has the ability to extrapolate the probable evolution of the current scene. Most of this research deals with the role played by the properties of a moving object, and, to a lesser extent, with how RM is modulated by the perceiver's knowledge of the moving target's physical characteristics, such as its shape (Kelly & Freyd, 1987; Nagaï & Yagi, 2001), direction (Halpern & Kelly, 1993; Hubbard, 1990; Munger, Solberg, & Horrocks, 1999), speed (Freyd & Finke, 1985), and acceleration (Finke, Freyd, & Shyi, 1986), all of which can act as cues to where the object is likely to be located in the future.

The study reported here falls in line with this research trend, which shows how RM can be modulated by the perceiver's previous knowledge. It looks at the impact of the participant's level of expertise—here, in automobile driving—and the impact of the participant's involvement in the action, on RM. Although most studies on RM have used relatively simple dynamic stimuli (a small number of items that are not action related), a study by Thornton and Hayes (2004; see also DeLucia & Maldia, 2006; Munger, Owens, & Conway, 2005) extended this effect to complex dynamic situations. The goal of the Thornton and Hayes study was to use an RM paradigm to directly assess the accuracy of visual memory for ego-position during movement in depth within a scene. A virtual desktop environment was set up to simulate a drive through a novel scene. The virtual environment contained a straight, single-lane grey road receding in depth over a green, textured-ground plane. The overall impression was that of a viewer in a car approaching a small village, driving through the village, and then continuing along the open road. Videos depicted a synthesized image of a road as seen from inside the car driving at 58, 65, or 72 km/hr. The observer's task was to detect an "unusual" interruption in the sequence. Participants watched road-scene videos that were temporarily interrupted by a black screen lasting 250 ms. After the interruption, the film continued and the participants had to judge whether the scene resumed at exactly the same point as it had stopped (normal-resumption condition) or at some other point. When the scene resumed at a different point, it could be either with a shift forward or with a shift backward. The results obtained showed that forward shifts were more difficult to reject than backward shifts. This study thus showed that RM can also be found in the case of dynamic scenes.

In a previous study (Blättler, Ferrari, Didierjean, Van Elslande, & Marmèche, 2010), we extended Thornton and Hayes's (2004) results by testing the impact of domain-specific expertise (in automobile driving) on RM, using real country road scenes (filmed with an on-board digital camera). The experimental paradigm was similar to the one used by Thornton and Hayes. Two groups of participants with different amounts of driving experience were tested: Inexperienced drivers who did not have their driving licence, and experienced drivers who had been driving regularly for a number of years. The results indicated that all participants of both driving-expertise levels exhibited an RM effect, but that experienced drivers exhibited a larger effect than inexperienced ones did. The findings of this experiment showed that knowledge acquired from years of driving modulates the effect of representational momentum on driving-scene judgements (see also Blättler, Ferrari, Didierjean, & Marmèche, 2011, for an expertise effect on RM in piloting).

The aim of the present study was twofold. The first was to see if the RM effect could be modulated by the involvement of the participant in the dynamics of the driving scenes. This was done by comparing more-active or less-active participants. The second was to generalize our results about the observed differences between novices and experts, to different kinds of real country roads, including winding roads, much less predictable than the straight ones used previously.

Concerning the first objective, we compared novices and experienced drivers who were simply like passengers in a car, with participants who were more involved in the driving action. These participants have to follow the road by turning a steering wheel, without nevertheless having the possibility to really act on the dynamics of the driving scenes. It was assumed that this direct manipulation of observer behaviour might provide insight into the underlying relationship between vision and action in our spatial world. In this vein, but in a very different context, Jordan and Hunsinger (2008) demonstrated that action control indeed has an impact on motion extrapolation. These authors compared the estimated vanishing points given by participants trained in advance to control the motion of a stimulus moving horizontally on a screen (using two buttons for increasing or decreasing the speed of the stimulus) to those of participants who did not have the opportunity to control the motion. The trained participants exhibited a larger RM effect. These findings show that processes associated with RM are mediated by action-related knowledge (see also Wexler & Klam, 2001; Wexler, Kosslyn, & Berthoz, 1998). In our study participants did not actually have any control on the movement of the road scene, but it is known that the simulation of the action and the action itself commonly share the same processes (e.g., Gallagher & Jeannerod, 2002) Taking a more ecological approach, Larish and Andersen (1995) presented displays that simulated flight (forward locomotion) over simulated terrains with mountains and buildings. Altitude and speed were fixed to maintain a consistent level of scene complexity while reducing task demands on the active controller. Active participants were told that they were to maintain a straight and level heading along the course on which the trial originated. They were also warned that continuous control would be necessary because of wind buffeting. All participants (active or passive) were told that a blackout would take place (as if flying into a cloud) during each trial, and they had to indicate whether they were positioned in the expected orientation following the blackout. The results indicated that active observers outperformed passive ones in detecting changes in orientation. These results are consistent with the proposal that active observers are more accurate at extrapolating orientation than are passive observers.

Concerning the second objective, we used winding roads in order to vary the predictability of the driving scenes. This allowed us to relate the results to those of our first research, where only straight, more predictable road were used (see Blättler et al., 2010). It is obvious that when we are moving along a straight road, it is easier to anticipate changes in the scene than when we are moving along a winding road. After a turn, the scene may change completely. New houses, new trees, new hills, and so on, may appear, making scenes on winding roads less predictable. Kerzel (2002) showed that when the direction of motion is less predictable, the RM effect is smaller. It was hypothesized that with practice in driving situations, the RM effect will increase, since the road environment becomes more and more predictable.

In the present study, all participants saw real driving scenes for 3 or 3.5 s, after which the video was cut and a black screen lasting 250 ms was displayed. Participants had to decide whether the video resumed at earlier point (backward) or at a later point (forward) than when it was cut. Participants were divided into four groups on the basis of their experience in driving and their involvement in the action as they viewed real driving scenes from the driver's point of view. They were either inexperienced in driving or very experienced. In order to have some of the participants get involved in the driving situation, half of them had to move a steering wheel to follow the path of the car. Although the steering wheel movements did not actually affect the scene, the participants were asked to turn the wheel to follow the curves of the road as closely as possible. However, no feedback was given in relation to their performance. Our predictions were as follows. First, the RM effect should be more pronounced for participants involved in the driving situation than for the others. Second, the RM effect should be more pronounced for experienced drivers than for inexperienced ones.

METHOD

Participants

Fifty-seven participants took part in the experiment. They were divided into four groups: Two groups of inexperienced drivers who did not have their driving licence, and two groups of experienced drivers who had been driving regularly for a number of years (at least 10). The first group included 14 inexperienced drivers who were assigned to the low-involvement condition (average age = 22.1 years, $SD = 2.63$). The second group contained 14 inexperienced drivers who were assigned to the high-involvement condition (average age = 21.55 years, $SD = 4.67$). The third group consisted of 16 experienced drivers who were assigned to the low-involvement condition (average age = 47.65 years, $SD = 10$). The fourth group was made up of 13 experienced drivers who were assigned to the high-involvement condition (average age = 44.3 years, $SD = 6.91$).[1]

Materials

The driving scenes were filmed with a digital camera (see Figure 1). The camera was positioned inside the car to film the driver's point of view. To avoid image instability, the camera was positioned on a board fixed on a mousse block on the dashboard and on the back seat, also in mousse. Thus, the road jolts were absorbed. The video montage was created by Pinnacle Studio Plus Version 10 software. The experiment was run on a Dell Latitude 120L portable computer. Thirty-two scenes were filmed (24 frames/s), corresponding to 16 different scenes of leftward curves and 16 different scenes of rightward curves. The car was always moving at a speed of 60 km/hr. Each scene (occurring in a different place) was used to generate nine videos that differed only in the size of the shift (−16 m, −12 m, −8 m, −4 m, 0 m, +4 m, +8 m, +12 m, +16 m). In each video, a black screen lasting 250 ms (interstimulus interval or ISI) was inserted after 3 s of the

[1] Note that in the present experiment (as in many studies on expertise), the age of the participants covaried with expertise. However, whereas nearly every study about age-related effects on cognition has found a decline or at least stability with ageing, in our previous experiment (Blättler et al., 2010) our older participants anticipated more than the younger ones did. The anticipation advantage acquired with the development of expertise may compensate for the deleterious effects of age generally observed (e.g., Rozencwajg, Lemoine, Rolland-Grot, & Bompard, 2005). In addition, DeLucia and Mather (2006) showed that age tended to slow down the extrapolation of motion. However, in their study, the older participants (mean age 58) were much older than the experienced drivers in our study. Furthermore, age-linked cognitive declines have mainly been demonstrated in individuals age 50 or older (Kausler, 1991; Salthouse, 1982).

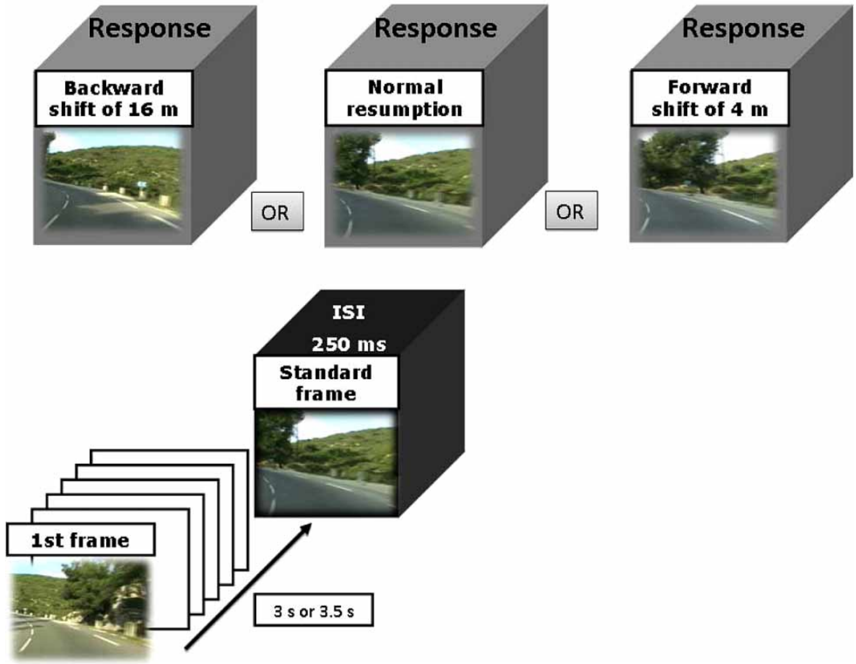

Figure 1. Experimental procedure. Participants watched a video for 3 s or 3.5 s. Then the video was stopped for 250 ms and started back up again after a shift forward (top right: Example of a forward shift of 4 m), in exactly the same position (top middle), or after a shift backward (top left: Backward shift of 16 m). To view this figure in colour, please see the online issue of the Journal.

video for half of the scenes, and after 3.5 s of the video for the other half. Following this interruption, the video resumed in one of nine conditions. In the normal-resumption condition, the video started back up exactly where it had been cut, i.e., the first image after the cut was identical to the last image before the cut (hereafter called the "standard frame"). In the forward-shift conditions, the video resumed at a point corresponding to +4 m, +8 m, +12 m, or +16 m past the location where the car was last seen (+4 m is the distance the car would travel in 250 ms at a speed of 60 km/hr). In the backward-shift conditions, the video resumed −4 m, −8 m, −12 m, or −16 m behind the interruption point. Participants assigned to the low-involvement condition answered with keystrokes. Participants assigned to the high-involvement condition answered with two buttons located behind the steering wheel (i.e., participants answered without taking their hands off the steering wheel). After the cut, the video continued either until the participant responded (forward or backward) or for 10 s, whichever came first.

Procedure

The experiment was run in two phases: A familiarization phase, followed by the experimental phase. Before the familiarization phase, the experimenter gave the participants the following instructions:

- *Low-involvement condition*. "You are going to see driving scenes showing curved roads. After a short while, the video will be stopped briefly. Upon resumption of the video, the location of the car on the road will be different. Either the car will have moved forward (forward shift) or the car will have moved backward (backward shift). Your task will be to indicate whether the car has shifted forward or backward." After reading the instructions, the participant was shown a right-curve scene (in all nine resumption conditions) and a left-curve scene (in all nine resumption conditions). The presentation of these 18 conditions was randomized. These two scenes were not presented in the experimental phase.
- *High-involvement condition*. "You're going to see driving scenes showing curved roads. You will have to follow the curve with the steering wheel. Please note that you will not see the effect of your steering on the action, but your steering movements will be recorded and compared to the actual trajectory of the car. After a short while, the video will be stopped briefly. Upon resumption of the video, the location of the car on the road will be different. Either the car will have moved forward (forward shift) or the car will have moved backward (backward shift). Your task will be to indicate whether the car has shifted forward or backward." After reading the instructions, the participant was shown a right-curve scene (in all nine resumption conditions) and a left-curve scene (in all nine resumption conditions). The presentation of these 18 conditions was randomized. These two scenes were not presented in the experimental phase. Before each video began, a message was displayed asking the participant to centre the wheel. After each response, bogus feedback on trajectory-following performance was given to keep participants engaged in the steering task. As the trials progressed, the feedback indicated a systematic, gradual improvement in performance. For example, after the participant's first response, "Average difference of 14°", was displayed on the screen. After the last response, "Average difference of 6°" was displayed.

After the familiarization phase, the experimental phase began. Thirty scenes each with nine videos (making for a total of 270 videos) were presented in a random order that was different for each participant.

RESULTS

Analysis of RM magnitude

To assess the RM magnitude, we computed the point of subjective equality (PSE) for each *participant*. This point is the theoretical value of the stimulus that the participant considers to be subjectively equal to the standard. It indicates the point of maximal uncertainty. This measure was computed by fitting the distributions of percentages of each participant (see Figure 2 for the mean percentages by group). Each PSE (Figure 3) was calculated from this curve by taking all responses of that participant into account. A positive PSE that was significantly greater than zero indicated an RM effect.

The mean PSE of experienced drivers assigned to the high-involvement condition (mean = 3.62 m, $SD = 5.88$ m) was significantly greater than zero, $t(12) = 2.21$, $p < .05$. The mean PSEs of experienced drivers assigned to the low-involvement condition (mean = -0.22 m, $SD = 2.99$ m) and of inexperienced drivers assigned to the high-involvement condition (mean = -0.16 m, $SD = 3.63$ m) were not significantly different from zero, $t(15) = -0.22$, $p = .7$, and $t(13) = -0.16$, $p = .8$. The mean PSE of inexperienced drivers assigned to

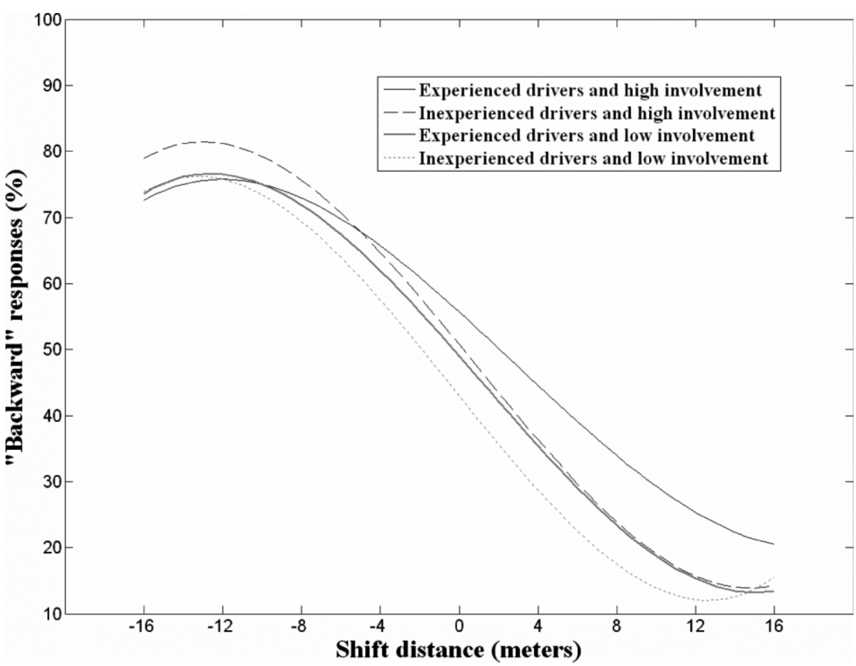

Figure 2. Percentage of backward responses, by expertise level, involvement level, and shift distance.

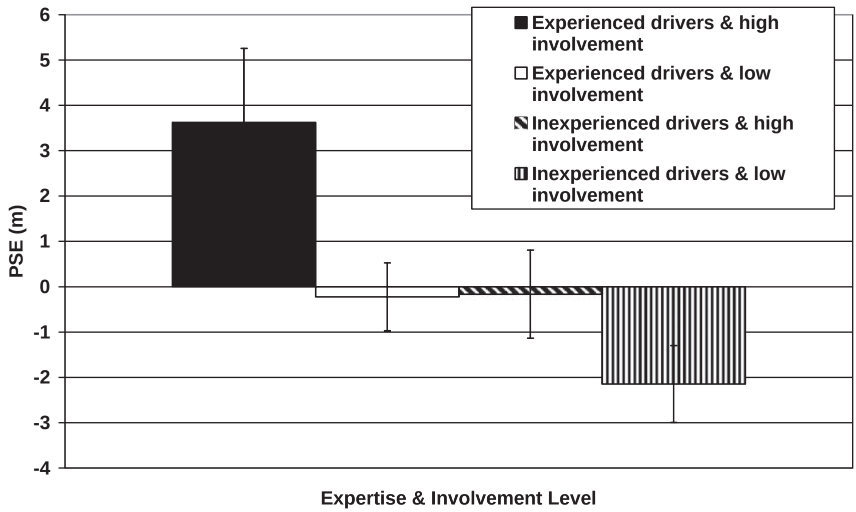

Figure 3. Mean PSE, by expertise level and involvement level. Error bars are standard errors.

the low-involvement condition (mean = -2.14 m, $SD = 3.17$ m) was significantly lower than zero, t(13) = 2.57, $p < .05$.

An ANOVA was conducted on the PSEs, with driving expertise (inexperienced vs. experienced) and extent of involvement (low vs. high) as between-participant factors. The expertise effect was significant, $F(1, 53) = 7.17$, $MSE = 115.47$, $p < .01$, as was the involvement effect, $F(1, 53) = 7.47$, $MSE = 120.37$, $p < .01$. The interaction between these two factors was nonsignificant, $F(1, 53) < 1$, $MSE = 12.38$, $p = .3$. Thus, experienced drivers demonstrated a greater RM effect than inexperienced ones did, and participants who were more involved in the action exhibited a larger RM effect than the less-involved ones.

In summary, when the video resumed in a forward direction, the more the participants were involved in the driving situation and the more driving experienced they had, the more they had trouble detecting the forward shift. It appears that both involvement in action and expertise play a role in the RM effect.

DISCUSSION

This study had two main objectives: Determine whether the RM effect can be modulated by participant involvement in the action, and whether the findings that RM is sensitive to expertise in the domain of automobile driving can be generalized to another kind of road (windings roads) that vary in scene predictability. On one hand, the results were expected, but in other aspects they seem rather puzzling. The results showed that, for the natural dynamic scenes we used, both dimensions (involvement in the action and expertise) modulated the RM effect. But the results also showed that only one of the four experimental groups obtained a significant RM effect.

Concerning the expected results, they confirmed those obtained by Thornton and Hayes (2004), who used synthesized automobile-driving scenes to demonstrate an RM effect not only in situations where participants were watching a scene containing a moving object or objects, but also in ones where the participants were an integral part of the movement (see also DeLucia & Maldia, 2006). They are also consistent with those we obtained in a previous study (Blättler et al., 2010) about the effect of driving experience on the magnitude of the RM effect. The more experienced the driver, the more likely he/she was to extrapolate forward, and the more difficult he/she had to see actual forward shifts. It is as if the participants—especially the most experienced drivers—had already anticipated the next stage of the scene at the moment when the video was interrupted. It could be that the newly presented scene (which in fact corresponded to a forward shift) seemed familiar for this reason. In short, expert knowledge had an impact on anticipation processes in dynamic-scene processing. These results extend earlier findings obtained in the few studies demonstrating RM modulation by domain-specific conceptual knowledge of the moving object (Vinson & Reed, 2002). They also show, as noted in certain models of expert memory (for a review, see Gobet et al., 2001), that expert perception of scenes differs from that of novices right from the perceptual encoding phase.

In addition, the present results showed that when the participants were involved in the driving scene, being required to follow the trajectory of the roads with the steering wheel, the RM effect was more pronounced. As a matter of fact, experienced and inexperienced drivers exhibit a stronger RM effect if they were asked to follow the road. This extra task is indeed very different from those classically used in the study of representational momentum (Hayes & Freyd, 2002). The dual task our participants had to manage was not independent of the main task. Both the driving task and the anticipation task had to be integrated into the same driving scenario. So the extra task was not in fact a distractive one. It follows that the interpretation proposed by Hayes and Freyd (2002) might be insufficient in this case. These authors found that when attention was distracted from an object undergoing simple, predictable translation in space, the RM memory shift increased. Our interpretation is that in the natural driving situations we used, and with our extra task which was integrated into the driving situation, some of the knowledge implied in the involvement in the action had an impact on RM. This seems to corroborate results obtained in other contexts (e.g., Jordan & Hunsinger, 2008; Wexler & Klam, 2001).

RM appears to be an adaptive perception–action linking process induced by neural transmission (Hubbard, 2005, 2006). As shown by Freyd (1983), a photograph of an action (e.g., a person jumping) is perceived as an action. Indeed, participants seem to encode the spatial position of what they see in the state it will be in a few moments later, i.e., they shift it in the direction of the current action. Action schemas present in long-term memory might be elicited when scenes referring to an action are being encoded. Kerzel and Gegenfurtner (2003) obtained results that support this idea. These authors compared the performance of participants on two RM tasks carried out in a dark room. In the first task, participants had to touch the area of the scene where they thought a moving target would vanish. These participants were able to use visuocognitive and visuomotor information (retinotopic spatial coordinates and egocentric spatial coordinates, respectively). In another task (same/different paradigm; see Freyd & Finke, 1984), the participants did not have visuomotor information at their disposal. The results showed that the participants who could rely on both visuocognitive and visuomotor information exhibited a larger RM effect than the ones who had only visuocognitive information. In our study, the high-involvement participants may therefore have used both visuocognitive and visuomotor information, while the low-involvement participants probably relied less on visuomotor information.

The most surprising result of this research is that only one of the four experimental groups we compared obtained a significant positive RM effect. This means that the RM effect might not be as general as it is usually thought to be. There seem to be many situations where the RM effect—which obviously has an adaptation function—is not always observed.

First, this finding raises a number of questions about the material we used in the present study. In our previous study (Blättler et al., 2010), only segments of straight roads were used. In the present study, the road sections were curved. With straight roads, observers could see far ahead and quickly pick out elements of the scene. With curved roads, this was not so easy because the angles of the curves were not wide enough for the participants to see the end of the curve. In this case, new information had to be gradually added as the video progressed, and the scenes were not easily foreseeable. This characteristic of the scenes may have been what modulated the magnitude of the RM effect. Looking into this hypothesis could be a promising approach for gaining deeper insight into how RM enters into of the representation of real dynamic situations involving a great deal of information.

It is also puzzling to note that novices with low involvement in the driving situation even showed a significantly negative PSE. These results are surprising because in a previous study (Blättler et al., 2010) a significant positive RM effect was observed for all participants. These results seem to be consistent, however, with Freyd and Johnson's two-component model (1987), which suggests that two processes affect memory-distortion effects: A representational momentum process and a process attributable to memory-averaging effects. Memory averaging consists of combining the target's different spatial positions before it disappears, which gives an averaged spatial position. The spatial representation of the target derived from its average position would lead to a greater memory shift in the direction opposite to the implied motion. So two competing effects would be at play: A positive memory shift attributable to representational momentum and a negative shift attributable to memory averaging effects. The process that benefits from the strongest activation would take priority over the other. In our experiments, if some features impede the RM process, then the memory-averaging process would receive the strongest activation (see also Hubbard, 1996). Nevertheless, it could be argued that responses are due not just to memory for the position before the cut, but to a combination of biases in memory for the position before the cut and memory for the position after the cut (for example, due to a Froehlich effect or an Onset Repulsion effect).

In addition, only the group of experienced drivers assigned to the high-involvement condition exhibited a positive RM effect, which means that having a lot of driving practice is not enough. Involvement in the driving action—even small, because participants are only required to react to the changes in the target—rather than proactively causing changes in the target, seems determinant. Being involved in this action may focus the driver's attention on the most relevant features of the scenes, and, with driving experience, the curves in the roads can be anticipated. Our results are in line with many studies on human navigation, which have identified improved way-finding by car drivers as opposed to car passengers (Peruch, Vercher, & Gauthier, 1995; Wilson, Foreman, Gilett, & Stanton, 1997). One of the reasons for these differences could be the manner in which the participants represent the space around them, i.e., the participant's task would play an important role in deciding where to look and what to attend to. Along this line, Wallis and Bülthoff (2000) showed that by introducing an active steering task, participants noticed changes in objects on the road more readily than ones off of it, and Witt, Profitt, and Epstein (2010) proposed that pragmatic perception relates the physical world to the perceiver's purposes and abilities.

Taken together, our results confirm that RM can be modulated by the participant's level of expertise (here, driving experience) and involvement in the action. In addition, the results showed that a positive RM effect is not always observed. The determining factors seem to be the characteristics of the dynamic scenes (see also Blättler et al., 2011, for a study of very unfamiliar dynamic scenes) and the degree of involvement of the observer. These results show that subtle relations between perception and action are at play. The Theory of Event Coding (TEC) developed by Hommel, Müssler, Aschersleben, and Prinz (2001) may be a relevant framework for interpreting our data. This theory postulates "that perceptual and action plans are coded in a common representational medium by feature codes with distal reference.

Accordingly, perceived events (perceptions) and to-be-produced events (actions) are equally represented by integrated, task-tuned networks of feature codes—cognitive structures we call event codes'' (p. 849). In our minds, however, we still need to determine how to operationalize these ''event codes'', and to find out how they are linked to the expertise-based acquisition of integrated representation structures, such as strategic and perceptual chunks for example (Gobet & Simon, 1996).

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