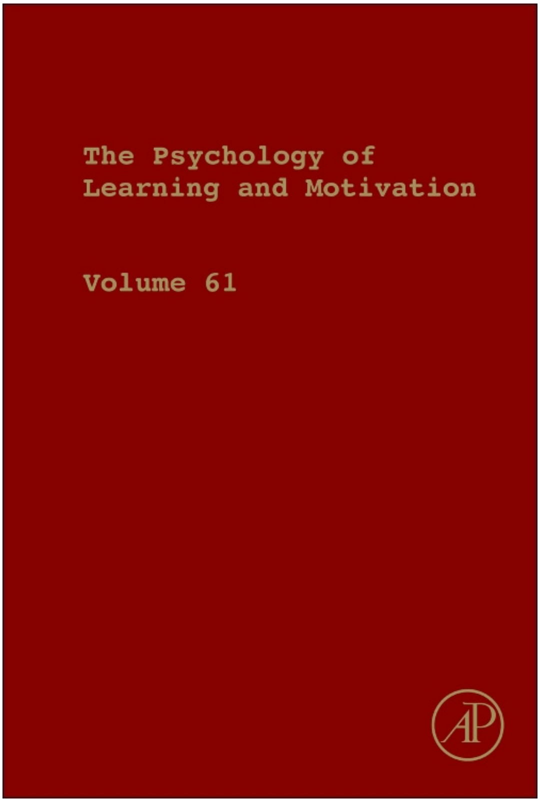

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CHAPTER SIX

Role of Knowledge in Motion Extrapolation: The Relevance of an Approach Contrasting Experts and Novices

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Contents

Abstract

One of the most powerful adaptive mechanisms available to the visuocognitive system for avoiding localization errors is to anticipate the probable evolution of the dynamic event as the environmental scenes are being perceived. For about 30 years now, this phenomenon has been studied in psychology in a field named "representational momentum" (RM). RM 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. In this chapter, we will focus on one aspect of this phenomenon: the role of knowledge present in memory. First, we will show that different forms of knowledge are

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likely to influence RM effect. Second, we will focus on one specific form of knowledge: expert knowledge. We will present studies using an expert–novice paradigm providing insight with regard to the mechanisms involved in RM effect. These studies notably show that RM effect is partly a "domain-specific" phenomenon, involving knowledge specific to each category of scenes and objects.

1. INTRODUCTION

The world we live in is a world that is constantly in motion. Objects move and even environments are constantly changing. Moreover, while we observe targets in motion, we too are often moving. For instance, when driving, we come across or overtake other cars in motion. The ability to anticipate the possible evolution of the moving targets we encounter is undoubtedly a critical element in man's adaptation to his environment. In the absence of this adaptation, and taking into account the delay in information processing, our decisions would be based on an obsolete representation of the world. A large body of psychological research has analyzed how the cognitive system processes this environmental constraint in real time: as soon as a scene has been cognitively processed, it has already changed.

In this chapter, we will focus on one specific aspect of this issue: how the cognitive system handles a brief interruption in the perceptual flow. When we are driving for instance, our perception is often interrupted. We blink, check our speed on the dashboard, or turn on windshield-wipers. Yet, after this brief interruption, although the scene has changed, we experience strong feelings of continuity with the scene preceding the interruption. For about 30 years now, this phenomenon has been studied in psychology within the field referred to as *representational momentum* (RM).

RM refers to the tendency of observers to "remember" the final position of a moving target as displaced forward in the direction of target motion (Freyd & Finke, 1984). The first part of this chapter seeks to describe this perceptual bias (for a more general description of this field, see Hubbard, 2005). Specifically, we will illustrate how the RM effect develops on the basis of physical characteristics of the object's movement (its speed, its direction) and its context. Second, we will show that within the framework of an RM task, processing the movement activates generic knowledge among observers, modulating the RM effect. We will also show that specific knowledge influences the RM effect. We will then present studies which, by contrasting experts and novices, argue in favor of a domain-specific effect, meaning, involving knowledge specific to each category of scenes and objects.

2. REPRESENTATIONAL MOMENTUM

2.1. Experimental Demonstration of the Phenomenon

In the seminal study by Freyd and Finke (1984), a rotation movement was implied by presenting a rectangle in three different orientations in succession. Each rectangle was presented for 250 ms and the interval between each presentation was 250 ms. Then a fourth rectangle was shown that either was in exactly the same position as the third rectangle or tilted in the same or opposite direction to that of the implied motion. Participants were asked to determine whether the fourth orientation was similar to the third (see Fig. 6.1).

Freyd and Finke (1984) results showed that participants had more trouble rejecting the rectangles whose orientation extended the implied motion than those indicating a backward movement. Similar results were not found when no movement was induced (for instance, when the order of the third and second orientations was reversed). According to the authors, participants appeared to encode the spatial position of the third orientation slightly ahead in the same direction as the implicit path of motion. They suggested that this pattern resulted from memory for the orientation of the final inducing

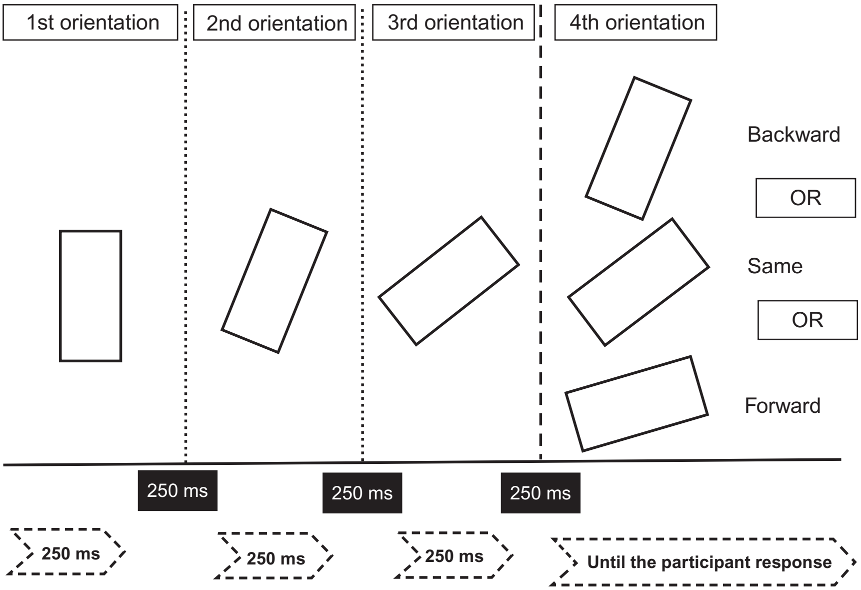

Figure 6.1 Procedure from Freyd and Finke (1984). The successive presentation of three orientations of a rectangle induces a movement of rotation of this rectangle.

stimulus being displaced forward, and given that they hypothesized this displacement reflected the effects of implied momentum, they referred to the forward displacement as RM. This phenomenon, RM, is a fundamental adaptation process that can even be observed using a static image implying motion. Freyd (1983) showed two photographs depicting an on-going action (for instance, a child jumping). These two photographs were presented in succession either in chronological order (*n* then $n+1$) or in reverse order ($n+1$ then *n*). Moreover, in some of the trials, the two photographs were identical (*n* then *n*). Participants were asked to state whether the pairs were identical or not. Results showed that the photographs presented in chronological order were harder to reject than those presented in reverse order (see also Freyd, Pantzer, & Cheng, 1988; Futterweit & Beilin, 1994).

While RM was initially revealed using very simple stimuli, it has also been observed using complex stimuli. Several studies have demonstrated, for example, that the movement of a target increasing in size (i.e., one whose size increases as it approaches) or shrinking (i.e., diminishes in size as the target moves away) provokes encoding the size of the target as larger when it is increasing and as smaller when it is decreasing (Hayes, Sacher, Thornton, Sereno, & Freyd, 1996; Hubbard, 1996; Nagaï & Yagi, 2001). Similarly, Munger, Solberg, and Horrocks (1999) presented three complex dimensional figures inducing rotation movements. Their results show that complex objects rotating in depth in the visual system also lead to an extrapolation of movement.

2.2. RM Shares Characteristics with Physical Movement

In one of their first studies, Freyd and Finke (1985) hypothesized the existence of an analogy between the anticipated and the real movement of an object. To test this hypothesis, they analyzed the object's velocity effect on RM. Using a protocol that was largely identical to the one used in their previous study (Freyd & Finke, 1984), two experimental conditions were compared: the induced movement was either quick or slow. Their results showed stronger RM effect when figures were presented with higher velocity of motion. Extending these studies, Finke, Freyd, and Shyi (1986) analyzed the impact of acceleration or deceleration of induced movement. They observed that when a figure appeared to accelerate, the spatial position represented by the observer was largely distorted as further along in the path of motion. By contrast, deceleration in the display of the figure reduced RM effect (for similar results, see also Finke & Shyi, 1988).

Following these preliminary studies on RM, Hubbard and Bharucha (1988) used a slightly different experimental paradigm. They showed participants a target (a point) moving in a continuous and rectilinear motion, either vertically (top to bottom or bottom to top, depending on the trials) or horizontally (right to left or left to right, depending on the trials). See Fig. 6.2 for an illustration. This movement is therefore an apparent motion and not an induced motion as was the case in the experiences described previously. After a few seconds, the target vanished without warning, and after the target had vanished, the observers used a computer mouse to position the cursor at the display coordinates at which they judged the target to have vanished.

Results showed that participants' memory for the location of the target was displaced along the direction of motion. This RM effect occurred with both vertical and horizontal motion.

An interesting aspect of this study is that Hubbard and Bharucha (1988) observed an unexpected result (see Fig. 6.2). Their findings showed that RM effect was smaller for bottom-to-top than for top-to-bottom displacement. Moreover, these authors also reported that horizontally moving targets were

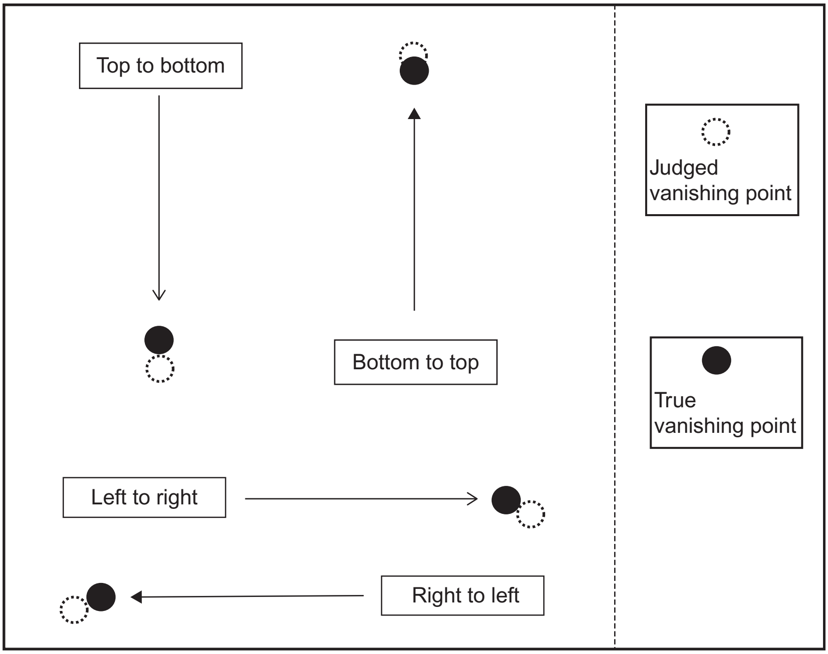

Figure 6.2 Material and results adapted from Hubbard and Bharucha (1988).

displaced downward below the path of motion (in addition to being displaced forward along the axis of motion). More recently, Hubbard (2001) reported that vertically moving targets that vanished high in the picture plane (i.e., descending targets that had fallen a shorter distance and ascending targets that had risen a longer distance) exhibited smaller forward displacement than did vertically moving targets that vanished low in the picture plane (i.e., descending targets that had fallen a longer distance and ascending targets that had risen a shorter distance). Hubbard (2001, 2005) argued that all these results were probably produced by the observer's knowledges about physical gravity laws. Gravity acts to decrease the forward velocity of a rising object and increase the forward velocity of a falling object.

Extending these results on the effect of gravity, Hubbard (1995) also studied the effects of friction on RM. He presented participants with a moving target (a square) which, depending on the experimental condition, was either in contact or not, with another static surface (a rectangle). He hypothesized that if knowledge of principles of physics has an impact on RM effect, when a moving target is in contact with another surface (existence of friction), a reduction in RM would be observed. Results effectively show that RM is smaller when targets are in contact with another surface (see also Hubbard, 1998; Kerzel, 2002).

These results provide convincing evidence that RM processes are influenced by observers' knowledge of physical principles, such as gravity or friction.

The studies presented highlight certain similarities between RM and real displacement from a spatial perspective. A few studies have analyzed whether these similarities exist as well from a temporal perspective. Freyd and Johnson (1987) addressed this question using Freyd and Finke's paradigm (1984, see Fig. 6.1). In their study, they varied the latency between the third and fourth orientation presented (from 10 to 900 ms). Their results showed that the RM effect increased with increased retention intervals. This highlights a new similarity between RM and real displacement: a moving object whose motion is suddenly hidden covers a longer distance when the retention interval is longer.

In sum, RM is a fundamental and adaptive phenomenon that has been highlighted across numerous situations. Confronted with a moving object, when the perception is interrupted for a short while, an observer always judges the last position of the object as further along in the direction of motion and further off in time than it was in reality. Moreover, this phenomenon is modulated by observers' knowledge of physical characteristics.

3. UNDERSTANDING THE IMPACT OF OBSERVERS' KNOWLEDGE OF OBJECTS

3.1. RM Is Influenced by Knowledge on the Context in Which the Motion Occurred

Following first RM studies that have been presented in the section 2.1, some studies explored how RM effect is influenced by knowledge. These studies showed that RM was influenced not only by major principles of physics such as gravity but also by knowledge on the context in which the motion took place.

In one such study, Bertamini (1993) presented observers with an image on which a circle was drawn on an inclined plane. Using a paradigm that was largely similar to that used by Freyd and Finke (1984), this first image disappeared from the screen and was replaced by a second image. In this second image, the circle was positioned either slightly above the initial position or slightly below it. Participants were asked to indicate whether the circle's position was identical for the two images. Results showed that images positioned below the initial circle were harder to reject than those positioned above the circle. This can be intepretated by the fact that context influences observers. In the real world, a ball on an inclined plane rolls downward. This knowledge appears to influence RM. To further extend his research, the author used different conditions, varying the angle of inclination of the plane. Results showed that the steeper the inclination, the stronger the RM effect. The context of the target object—the inclined plane in this case—is therefore taken into account by the mechanisms responsible for RM.

In a series of studies that also addressed the effect of context (Hubbard & Bharucha, 1988), participants were shown a target enclosed within a frame, moving either horizontally or vertically at a constant speed. From time to time, the target bounced off the inner walls of the frame. Depending on the trials, it disappeared prior to collision with a wall of the frame, at the moment of collision with the closest wall or after collision. Participants were asked to position the cursor over where they considered the target to have vanished. Results showed that in positions prior to collision or at the moment of collision, the direction of displacement was opposite to the direction of motion. This suggests that participants anticipated that the target would rebound on the walls of the frame, thereby changing its direction. In line with this, studies carried out by Verfaillie and d'Ydewalle (1991) show that complex motion "patterns" can influence extrapolation. The paradigm used was similar to that used by Freyd and Finke (1984); however, Verfaillie and d'Ydewalle introduced conditions in which successive rotations of a rectangle changed direction from time to time (see Fig. 6.3). The moving target could thus be described from a local perspective (clockwise motion) as well as from a global perspective with regard to the periodic motion of the moving target (clockwise then counterclockwise motion, etc.).

The key point in this analysis concerns the cases where the target disappears just before the breaking point. The results clearly show that the extrapolation of motion is no longer observed at these points of disruption. This demonstrates that the memorization of the final orientation of the rectangle presented is influenced by the anticipation of the target's global motion and not merely by an extrapolation of its local motion. These findings suggest that observers could have extracted the regularities that govern this global motion. Observers thus anticipate motion using acquired knowledge (the extracted regularities) and not simply on the basis of perceived motion. Understanding the nature of the different forms of knowledge involved in this effect is thus a fundamental issue.

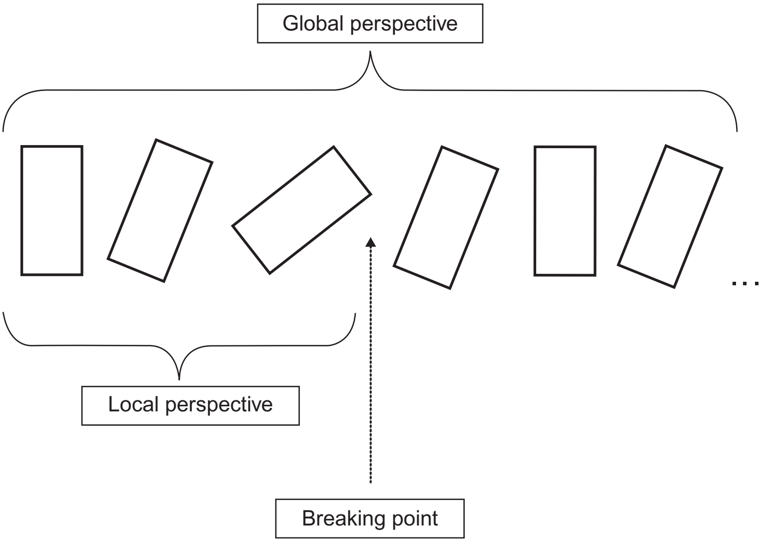

Figure 6.3 Material adapted from Verfaillie and d'Ydewalle (1991). The rectangle is presented successively in different orientations that induce a rotational movement. At various times the rotation moves in the opposite direction (breaking point).

3.2. The Knowledge Involved in RM Is Sometimes Naïve Conceptions of Physical Principles

A number of studies have shown that physical knowledge used in RM effect is often implicit and naïve rather than explicit expert knowledge. This distinction is particularly well illustrated in a study carried out by Freyd and Jones (1994). These authors analyzed RM in a situation where a ball was shot through a spiral tube (see Fig. 6.4). Participants were asked to state where the ball was positioned a few moments after exiting the tube.

Results showed that participants selected the spiral path as the ball's anticipated trajectory (i.e., a trajectory influenced by a spiral form, see section B of Fig. 6.4). However, results from a posttest questionnaire showed that over 60% of the participants chose "straight path" as the ball's expected trajectory after exiting a spiral tube (see section A of Fig. 6.4). The RM effect observed therefore reflects naïve physics rather than explicit knowledge of physical laws among participants (Zago & Lacquaniti, 2005). Similar results have been found by Kozhevnikov and Hegarty (2001) who focussed on explicit and implicit knowledge of physical principles. In this study that was carried out among physics experts and novices, the authors elaborated an RM paradigm that required specific physical laws (notably gravity). Results showed that both novices and experts (despite the fact that the latter were able to correctly state physical laws) continued to exhibit implicit impetus beliefs. In this experiment, when impetus beliefs and Newtonian theory made different predictions, experts exhibited the same implicit impetus beliefs as novices when asked to respond in an RM paradigm.

The findings we presented above are consistent with the view that RM is under the influence of "naïve" knowledge rather than expert knowledge.

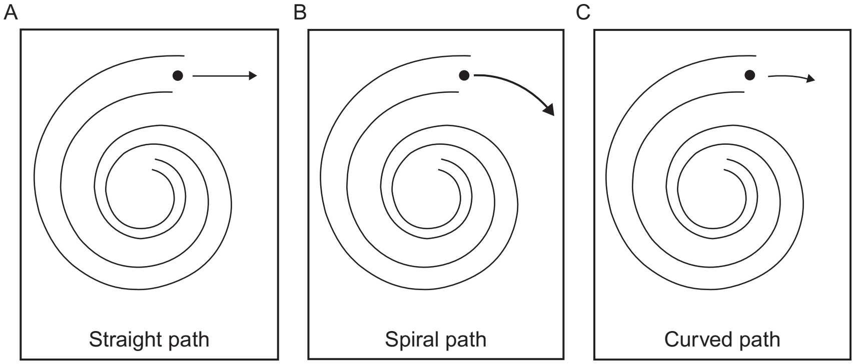

Figure 6.4 Material adapted from Freyd and Jones (1994).

Nevertheless, we think that these studies have given themselves little chance to observe an influence of expert knowledge. In particular, this could be a consequence of the highly artificial aspect of the situations presented in most of these studies. Studies on expert memory have shown that expert knowledge is essentially highly specific knowledge, which cannot be transferred to situations that are not closely linked to the domain of expertise (see, for instance, Chase & Simon, 1973; Unterrainer, Kaller, Halsband, & Rahm, 2006; for a review, see Gobet, 1998; Didierjean & Gobet, 2008). In the following sections, we will show that object-specific knowledge can also influence RM and that the impact of RM can also be highlighted using valid ecological material. We will then show that based on this kind of paradigm, it is possible to demonstrate that expert knowledge influences RM, and thereby advance our understanding on the nature of knowledge involved.

3.3. The Role of Knowledge With Regard To the Specific Characteristics of Each Object

One of the most elegant studies showing object-specific effects on RM was conducted by Vinson and Reed (2002) (see also Reed & Vinson, 1996). These authors carried out an RM experiment using drawings representing objects. Each drawing was successively presented four times during 250 ms and was shifted each time 15 mm higher or lower than the previous one. A fifth drawing was then shown and subjects were to determine whether this last one was at the same position as the fourth drawing shown. The authors demonstrated that the size of RM was related to the nature of objects. A greater memory shift was induced by a weight stimulus when implied motion was downward and by a rocket stimulus when implied motion was upward. A building did not elicit different memory shifts for upward and downward movement. Vinson and Reed also showed that despite having *identical visual features*, the "rocket" and "building" stimuli produced different results (see Fig. 6.5). While the rocket showed greater memory shift for upward implied motion, the same drawing labeled "building" did not elicit similar results. These findings show that RM is affected by participants' knowledge of perceived objects. Why is it then that the few studies that have attempted to vary the expertise level of participants have failed to show an impact of expert knowledge (for instance, Kozhevnikov & Hegarty, 2001; Zago & Lacquaniti, 2005)? Probably because the paradigms used are far removed from the "natural" conditions

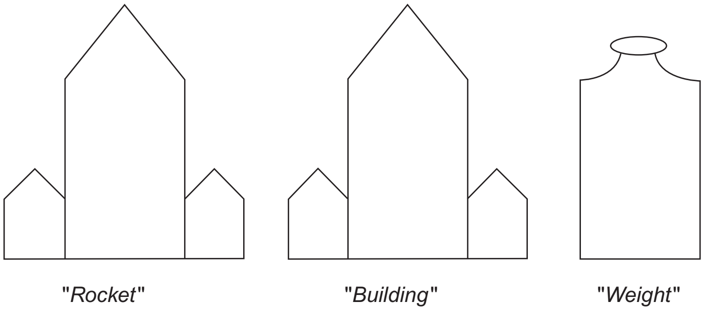

Figure 6.5 Material adapted from Vinson and Reed (2002).

where expertise occurs. In the next section, we will present a study that shows that the effects of RM can also be illustrated using more ecological material.

4. RM IS MODULATED BY EXPERT KNOWLEDGE

This section seeks to show that expert knowledge, which most of the time is very specific within a given domain, modulates RM. Its objective is twofold: first, we will show why integrating natural and realistic scenes is an indispensable condition in highlighting the effects of expert knowledge on RM. Second, we will present the experimental results from a series of studies conducted among experts and novices in different domains; these results show that the RM effect is modulated by expertise, enabling us to extend our understanding of the knowledge at stake.

4.1. Integrating Dynamic and Natural Scenes in RM Experimental Paradigms

We think that classic RM tasks, such as those we have presented above, do not enable an observer to bring into play his/her expert knowledge, as the situations presented are rather artificial. Which observer is expert in the perceptual processing of a rectangle turning around, a shifting point or a pointing building? Analyzing how the RM effect is modulated by expertise undoubtedly requires the development of an experimental paradigm presenting a dynamic scene within a realistic frame and specific to a domain of expertise.

Thornton and Hayes (2004) presented several experiments demonstrating RM effects with tasks using relatively natural scenes. One of their experiments presented synthesized images of movie sequences showing a driver's view along a scenic roadway. This virtual environment contained a straight, single-lane gray 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/h. The observer's task was to detect an "unexpected" 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 natural scenes, further confirming the adaptive dimension of anticipation mechanisms. In the next section, we will show how this paradigm can be used to analyze whether RM is influenced by explicit knowledge that is specific by nature.

4.2. RM Among Experienced and Inexperienced Drivers

In several studies (Blättler, Ferrari, Didierjean, & Marmèche, 2012; Blättler, Ferrari, Didierjean, Van Elslande, & Marmèche, 2010), we tried to test the impact of domain-specific expertise, automobile driving, on RM, using films of road scenes, and to find out whether the improved anticipation ability that comes with greater expertise is transferred to scenes from domains that are far removed from the individual's domain of expertise.

In a first study, experienced automobile drivers and inexperienced automobile drivers performed a movement-anticipation task on realistic road scenes (i.e., automobile driving filmed by an onboard camera). Our idea was to use an RM task in order to find out whether an expertise effect occurs as early as the perceptual encoding phase.

In this experiment, the participants were divided into two groups on the basis of their driving experience: "inexperienced drivers," who did not have their driver's license, and "experienced drivers," who had been driving regularly (for at least 2 h a day) for an average of 18 years. They viewed road scenes filmed by an onboard camera. The car was constantly moving at a speed of 60 km/h. The scenes were interrupted by the display of a black screen lasting 250 ms and then resumed in one of three conditions: a shift forward (with respect to the car's direction of movement), a shift backward (in the direction opposite to the car's movement), or no shift (at exactly the same point as before the interruption, normal-resumption condition). In the shift conditions, the size of the forward and backward shifts was manipulated (3, 6, 9, and 12 m). Figure 6.6 gives an illustration of a standard frame, a 12-m shift forward, and a 12-m shift backward.

The task was a same/different comparison task. Participants had to compare the last scene viewed before the cut, to the first scene viewed after the cut, and decide whether or not the two scenes were the same (i.e., whether the vehicle was in the same location in both scenes). Our hypotheses were that if more RM effect is observed in experienced drivers than inexperienced ones, then in the normal-resumption condition, experienced drivers should make significantly more errors than inexperienced ones. In the forward-shift and backward-shift conditions, if participants anticipate, they should have more trouble deciding on forward shifts (than on backward shifts) whether or not the first image seen after the cut is different from the last image seen before the cut. Accordingly, if experienced drivers anticipate more than inexperienced ones, then we can expect the asymmetry between forward and backward shifts (on "same" responses) to be greater for experienced drivers than for inexperienced ones.

First, the results of this experiment indicated that all participants of both driving-expertise levels exhibited an RM effect; the error rate was significantly higher for forward shifts than for backward ones. This finding obtained with real videos corroborates those obtained with synthesized images by Thornton and Hayes (2004). Concerning the main goal of this study, that is, to explore the effect of domain-specific knowledge on motion anticipation, the results showed that the experienced drivers did indeed anticipate more than the inexperienced. For example, the experienced


12 m backward Standard frame 12 m forward

Figure 6.6 Example of material used in Blättler et al. (2010, Experiment 1). The standard frame (in the middle) was the last image seen before the cut. The video resumed after a backward shift of 12 m or a forward shift of 12 m.

drivers made more errors when the video resumed at exactly the same point as before the cut. Knowledge acquired from years of driving modulates the effect of RM on driving-scene judgements. These results extend earlier findings from the few studies demonstrating RM modulation by the observer's 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 Didierjean & Gobet, 2008), that expert perception of scenes differs from that of novices right from the perceptual encoding phase.

In a second part of this experiment, we aimed at determining whether this expertise effect is due to the existence of a general anticipation ability acquired with driving expertise, or whether the knowledge developed by experienced drivers is domain specific. In this second part, the same experienced drivers and inexperienced drivers as in the first part performed two RM tasks with stimuli not involved in driving. One task showed a black square moving from left to right across the screen; the other showed a film of a person running (see Fig. 6.7). In each trial, 2 s after the beginning of the video, a black screen was displayed for 250 ms. After the interruption, the video resumed in one of the same conditions as in the first experiment (normal-resumption condition, forward-shift conditions, and backward-shift conditions). Our goal was to find out if the knowledge mobilized in RM tasks is partly task specific. Most studies on cognitive expertise have shown that expert knowledge is not transferred to material that is not from the expert's domain (e.g., Chase & Simon, 1973; Ericsson, 1985; Hatano & Osawa, 1983; Unterrainer et al., 2006; see however Gauthier, Williams, Tarr, & Tanaka, 1998; Tanaka, Curran, & Sheinberg, 2005). With this

Figure 6.7 Examples of material used in the second part of the Blättler et al. (2010)'s article. Left: The image is a screen print of a video showing a person running from right to left. Right: The image is a screen print of an animated square moving from left to right.

hypothesis, we can expect no differences between experienced and inexperienced drivers in terms of movement anticipation.

The results showed that for both natural scenes and artificial scenes, all participants exhibited an RM effect. As a whole, the participants made judgement errors in the normal-resumption condition, and their forward-shift and backward-shift responses were asymmetrical (i.e., there were more mistakes on forward shifts than on backward ones). These results thus provide further evidence of an RM effect in dynamic situations. Unlike the first part of the experiment, however, there was no anticipation difference between the two groups of participants (experienced or inexperienced drivers). The main finding of this second part of the experiment is that knowledge acquired in a specific domain (here, automobile driving), which led to RM modulation with experience, was not transferred to dissimilar domains.

Correlations were calculated in order to relate the participants' performance in both parts of the experiments. No correlations were found between the different types of scenes, for either group of participants. This second result argues in favor of the presence of RM components specific to the scenes presented. In a second study, we tried to extend these results to a new expertise domain. We used novices and expert pilots and simulated aircraft landing scenes (Blättler, Ferrari, Didierjean, & Marmèche, 2011).

4.3. "True Novices." A Study with Expert and Novice Pilots

Our main goal was to find out whether RM would be observed for "true" novices, or whether this effect requires some minimal amount of knowledge of the scenes observed. One of the limitations of the study we have presented above was that the inexperienced drivers were not "true" novices. As car passengers, the novices must have seen the same types of visual scenes as the experienced drivers. Indeed, Jordan and Hunsinger (2008) argued that even riding in an automobile can modify the person's perception of the driving situation he/she observes. This question is important at a more general level because, although RM is a particularly robust phenomenon (Courtney & Hubbard, 2008; Ruppel, Fleming, & Hubbard, 2009) that has been observed in many different situations, in the vast majority of studies, the observers were not actually real novices relative to the scenes presented.

In our experiment, visual simulations based on synthesized images of aircraft landing scenes, seen from the viewpoint of the pilot, were used in an RM task. We tested 15 expert pilots from the French Air Force and

21 novice participants, who had never been in the cockpit of an airplane or on board an aircraft simulator. The speed chosen for the landing was a standard speed for a military jet fighter (i.e., the distance the aircraft travels during 125 ms is about 7 m at a speed of 200 km/h). As in our precedent studies, the scenes were interrupted by the display of a black screen lasting 125 ms and then resumed in one of three conditions: a shift forward (with respect to the aircraft's direction of motion), a shift backward (in the direction opposite to the plane's motion), or no shift (i.e., at exactly the same point as before the interruption). In the shift conditions, the size of the forward and backward shifts was manipulated (125, 250, 375, and 500 ms). Participants had to compare the last image seen before the cut to the first image seen after the cut and decide whether the scene had shifted backward or forward.

First, as in our experiments with expert drivers, we observed that expert pilots anticipate more than novices do in their knowledge domain. When the scene resumed at exactly the same point as before the cut, the piloting experts answered "backward shift" significantly more often than the novices did. When the video resumed with a forward shift, the experts again responded "backward shift" significantly more often than the novices did, especially on the smallest forward shifts.

Second, the main goal of the present study was to find out whether RM would be observed for "true" novices, or whether this effect requires some minimal amount of knowledge of the scenes observed. Here, the RM effect was not detected for the novices. A few rare experiments have shown that RM can be eliminated when the direction of motion cannot be anticipated (e.g., Kerzel, 2002) or when distractors are presented during the retention interval (e.g., Kerzel, 2003). Distractors during the retention interval seem to stop the mental extrapolation of the target. The presence of such distractors may disrupt the flow of attention allocated to the moving target and thereby cause RM to decrease. With this finding in mind, we tested in a control experiment the hypothesis that with a longer inter stimuli interval (ISI), more time could be allotted to the mental extrapolation of the dynamic scene, and that this additional time might allow RM to show up, even among novices. Therefore, in a control experiment, ISI duration was doubled (from 125 to 250 ms) and the same shift sizes were used. The results were very similar to those obtained in our first experiment. For novices in these experimental conditions, we were not able to demonstrate RM. To rule out the possibility that the novices were perhaps an outlier group with unusually small RM in general, a control task was proposed to these same novices. We chose the classical (Hubbard, 2001) task of a moving square on a plain background, the same as the one we used in our previous research (Blättler et al., 2010). Results showed that our novices, as all participants of previous research, exhibited an RM effect.

Our main question in this research was whether or not the mechanisms responsible for RM might be generic (i.e., general or not domain specific). In this study, experts showed a strong RM effect, whereas anticipation was not detected for the novices in several experimental conditions. Taken together, these results clearly support the hypothesis that RM relies at least partially on specific knowledge stored in long-term memory.

The RM observed here with the expert pilots can be considered to reflect very good adaptation by the visual system of experts. In this line, Hayhoe (2009) showed that memory may play a part in controlling visually guided behavior. Observers are thought to learn the dynamic properties of the world in order to direct their gaze where it is needed. In dynamic environments such as driving, they would learn the complex properties of the moving environment. For Hayhoe, evidence of such learning is the fact that saccades are often directed toward a location in a scene in advance of an expected event. For example, in Land and McLeod's (2000) study of cricket, batsmen anticipated the ball's bouncing point so that the eye arrived at that point 100–200 ms before the ball did. The ability to predict where the ball will bounce would rely on previous experience of the ball's trajectory. The saccades were always preceded by a fixation on the ball as it left the bowler's hand, suggesting that the bouncing-point predictions were based on both current sensory data and prior experience of the ball's motion. The authors concluded that observers store internal models of the dynamic properties of the world that can be used to position the gaze in anticipation of a predicted event. The participants' anticipatory saccades and pursuit movements revealed that acquisition of visual information is planned for a predicted state of the world. Such predictions have to be based on a stored memory representation. And the accuracy of the predictions reveals the quality of the information in the stored memory or internal model. Spatial and temporal accuracy of eye saccades and fine-tuning of these movements following a change in the moving object's dynamic properties would indicate that subjects have an accurate internal model of the object's spatiotemporal path, and that they rapidly update this model when errors occur. As Hayhoe (2009) stressed, the development of internal models occurs over long periods as a result of extensive practice. The data we collected seem to point in this direction. It takes years of experience before an expert pilot becomes capable of anticipating the spatiotemporal evolution of landing scenes in order to fill in the visual gap in what is perceived. Such anticipation processes are likely to help pilots manage the control strategies they use. Following the pioneering work by De Groot (1965) and Chase and Simon (1973), a large number of studies have shown that expertise in a domain considerably modifies the perceptual encoding of domain-specific elements present in the scene (e.g., Reingold, Charness, Pomplun, & Stampe, 2001). Thus, it is possible that expert pilots extract different information that promotes RM.

5. CONCLUSION

The objective of this chapter was to present some of the studies which show that RM is influenced by knowledge. One of the recurrent questions in cognitive psychology concerns knowing whether generic mechanisms, in which similar processes are applied to all situations, underlie a given behavior, or whether specific mechanisms that are different for each situation are used. Analyzing this issue is complex as in most of the domains studied in psychology, participants are all experts in the task proposed (for instance in most of the studies on face recognition), or on the contrary, all novices (for example in the tasks used to analyze working memory). In both cases, it is difficult to determine what falls within specific knowledge and what falls within generic knowledge. As the studies we have presented show, comparing experts and novices in the RM domain offers an interesting tool with which we can address this issue. Our results show that at least partly, RM is undoubtedly influenced by specific knowledge with regard to each category of scenes.

Putting into perspective the studies in the domain of cognitive expertise and RM undoubtedly offer an additional advantage. Over the years, the cognitive expertise domain has developed theories that provide precise description of the architecture of expert knowledge in memory (see, for instance, Gobet & Simon, 1996, 2000). These models have pointed out that in expert memory, knowledge develops in a highly specific form, named "chunk" (e.g., Chase & Simon, 1973; Gobet et al., 2001). In chess for instance, chunks are familiar patterns of pieces commonly found in chess games. Expertise is acquired through the learning of a very large number of chunks indexed by a discrimination network. Such networks enable the rapid categorization of domain-specific patterns and account for the speed with which expert players "see" the key elements of a problem. In these theories, chunks have an anticipatory character: they possess information on the most probable follow-up of actions which activate them. To date, this characteristic of expert memory has been essentially demonstrated with strategic knowledge, for instance tactical schemas in basketball (e.g., Didierjean & Marmèche, 2005) or chess openings (e.g., Ferrari, Didierjean, & Marmèche, 2006). Putting into perspective the studies in the domain of cognitive expertise and RM is undoubtedly interesting in these two domains. Studies on expertise propose specific models of knowledge involved in anticipation. For their part, studies on RM present a well-grounded experimental and theoretical framework to extend these models to the first phases of perceptual encoding.

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