The Expertise Reversal Effect for Sequential Presentation in Dynamic Soccer Visualizations

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Cognitive load perspective was used as a theoretical framework to investigate effects of expertise and type of presentation of interacting elements of information in learning from dynamic visualizations. Soccer players (N = 48) were required to complete a recall reconstruction test and to rate their invested mental effort after studying a concurrent or sequential presentation of the elements of play. The results provided evidence for an expertise reversal effect. For novice players, the sequential presentation produced better learning outcomes. In contrast, expert players performed better after studying the concurrent presentation. The findings suggest that the effectiveness of different visual presentation formats depend on levels of learner expertise.

Keywords: animation, learning, expertise reversal, cognitive load, soccer, sequential presentation

Static diagrams have long been used by team-sport coaches to illustrate the functioning of a playing system and describe the movements of players in the field through the use of schematic elements such as cross and arrow. In recent years, with the growth in graphic technologies, such visualizations have become dynamic, more realistic, and displaced from traditional media like blackboard to the computer. From an intuitive perspective, dynamic visualizations (e.g., animations and videos) are believed to have an enormous potential for improving players’ tactical skills because they can deliver explicitly the information concerning the spatiotemporal changes over time (e.g., motion, acceleration, and trajectory). Thereby, they may compensate the inability of learners to mentally infer these changes from static visualizations. It can also be assumed that recall of information related to team sports could be enhanced when subjects learn in dynamic conditions, which present a set of contextual features (e.g., change-related information) analogous to those experienced in realistic game conditions (the encoding specificity principle; e.g., Tulving & Thomson, 1973). According to the congruency principle (Tversky, Morrison, & Bétrancourt, 2002), dynamic visualizations are considered the most suited and natural instructional means when they are used to portray a content characterized by a high level of dynamism because they can convey this dynamism in a direct and explicit way (Scheiter & Gerjets, 2010).

Despite the presumed advantages of dynamic visualizations, some studies have shown that the temporal constraints of animations may impose a high cognitive load on the learners’ working memory (WM) and actually decrease performance when compared with learning from static pictures (e.g., Hegarty, Kriz, & Cate, 2003; Mayer, Hegarty, Mayer, & Campbell, 2005; Tversky et al., 2002). A number of researchers have suggested that certain design techniques may be employed to overcome these difficulties. These include, for example, altering the animations’ presentation speed (e.g., De Koning, Tabbers, Rikers, & Paas, 2011; Fischer, Lowe, & Schwandt, 2008; Fischer & Schwan, 2010), using attentional cueing (e.g., De Koning, Tabbers, Rikers, & Paas, 2007), and segmentation (e.g., Spanjers, Wouters, Van Gog, & Van Merriënoor, 2012). Since such techniques are based on theory and research in cognitive psychology, they have been referred to as cognitive principle design (Hegarty & Kriz, 2007).

In the current study, we suggest a novel instructional technique called the sequential presentation method, which involves displaying parts of the dynamic visualization in a successive way rather than in a simultaneous way. Even though this type of presentation has been frequently
used with static visualizations such as statistical formulas (e.g., Kester, Kirschner, & Van Merrienboer, 2004) and diagrams (e.g., Bétrancourt, Bisseret, & Faure, 2001; Bétrancourt, Dillenbourg, & Montarnal, 2003; Jamet & Arguel, 2008; Jamet, Gavota, & Quaireau, 2008), there have hardly been any investigations with dynamic visualizations. Furthermore, reviews and empirical studies of the expertise reversal effect (e.g., Kalyuga, 2007; Kalyuga, Ayres, Chandler, & Sweller, 2003; Lee & Kalyuga, 2011) have demonstrated that instructional design methods that have a positive effect for experts might have no, or even a negative effect for novices. This study investigated whether an expertise reversal effect would occur for the sequential presentation method used with animated soccer visualizations.

**Learning From Dynamic Visualizations and Cognitive Load**

To derive meaning from a complex dynamic system such as a soccer-playing system, players must develop several types of knowledge (Hegarty & Just, 1993; Narayanan & Hegarty, 1998). Firstly, it involves knowledge of the components of the system (i.e., teammates, opponents, and ball) and how they are placed and organized in the field, that is, the configuration of the system. Secondly, it includes knowledge of how the players move and affect each other’s motions, that is, the behavior of the system. Finally, it involves understanding of the function of the playing system and what it is designed to do. Effective integration of these types of knowledge allows players to construct an internal representation called mental model that depicts precisely the playing system (Kriz & Hegarty, 2007). North and colleagues (e.g., North, Ward, Ericsson, & Williams, 2011; North, Williams, Hodges, Ward, & Ericsson, 2009; Williams, Hodges, North, & Barton, 2006) extended this knowledge and showed, using point light, that the effective perception of dynamic soccer scenes requires players to process the structural, relational information between display features (e.g., movements and relative positions of the players) rather than identifying superficial, low-level surface features (e.g., background information, isolated distinctive actions).

However, research within cognitive load theory (Sweller, Van Merrienboer, & Paas, 1998; Paas, Renkl, & Sweller, 2003, 2004; Sweller, Ayres, & Kalyuga, 2011) indicates that animations are often too complex to be easily perceived and processed in WM (cf. the apprehension principle in Tversky et al., 2002). According to this theory, capacity and duration limitations of WM as a major component of human cognitive architecture may critically influence the effectiveness of learning new information from various instructional procedures and presentation formats. In particular, animations may impose the following two types of cognitive load that can seriously impede learning.

*The extraneous cognitive load* is a type of load that is not actually required for achieving learning goals but is imposed due to the design of information presentations. With animations, it could be caused by the fleeting nature of such information presentations (transient information effect; e.g., Sweller et al., 2011) imposing significant WM demands. When dealing with animated information, learners are required to temporarily hold in WM the current information (A) while attending to the succeeding information (B). If information (B) is processed before the information (A) is committed to long-term memory (LTM), information (B) may interfere with information (A). This phenomenon, called interference, or retroactive inhibition, could overwhelm WM (Mayer, DeLeeuw, & Ayres, 2007). For example, it has been known that storage of dynamic soccer information (e.g., relative movement of the players) in WM suffers as a function of retroactive interference (Khacharem, Zoudji, & Ripoll, 2013; North & Williams, 2008)

Furthermore, the extraneous cognitive load might also be due to the high perceptual (attentional) demands, since the learners’ visual attention could be spatially distributed over the different elements moving at once (split-attention effect, De Koning, Tabbers, Rikers, & Paas, 2009). As a result, some of the presented elements will receive learners’ attention whereas others could be overlooked. Lowe (1999) demonstrated that learners, especially novices, found it difficult to detect and integrate the relevant information conveyed by dynamic visualizations (weather maps), because their visual attention was often diverted by salient features, such as fast movements, that were not necessarily relevant for understanding the content.

*The intrinsic cognitive load* is determined by interactivity of the elements of information that are essential for learning. An animation that contains a large number of interacting elements is considered as more difficult to learn from than animation with a smaller number of interacting elements. Low interactivity animations mostly consist of single elements that can be learned in isolation, whereas in high interactivity animations, individual elements can only be well understood in relation to other elements (Sweller, 1994; Sweller et al., 1998). Intrinsic load is also influenced by learners’ prior knowledge because, as a result of their experience within a domain, learners can develop extensive cognitive schemas in LTM that enable them to encapsulate several elements into larger chunks or templates that are treated as single units in WM. Thus, the same animation might generate less intrinsic load for learners with higher levels of prior knowledge than for learners with lower levels of prior knowledge (Khacharem, Spanjers, Zoudji, Kalyuga, & Ripoll, 2013; Spanjers et al., 2011).

**Sequential Presentation Method and Levels of Learner Expertise**

In some circumstances, the level of element interactivity of an instructional presentation may be too high to be accurately understood by the learners. In this case, it may be helpful to first present the material as isolated elements that could be processed serially rather than concurrently.
By presenting the elements of complex information sequentially, the learners could perceive lower intrinsic cognitive load because the element interactivity of the material would be artificially reduced (Van Merriënboer & Ayres, 2005).

The added value of the sequential presentation is widely attested in learning from static pictures/diagrams presented alone (e.g., Bétrancourt & Tversky, in press; Bétrancourt et al., 2001) or associated with either written text (e.g., Bétrancourt et al., 2003; Wright, Hull, & Black, 1990) or spoken commentary (Jamet & Arguel, 2008). For example, using a geographic map as learning material, Bétrancourt and Tversky (in press; Experiment 3) showed that a meaningful sequential presentation of the map's components allowed faster processing and more accurate recall performance than the static display of the map. Bétrancourt et al. (2003) found that learners, who studied a sequential presentation of financial concepts, achieved higher performance scores than learners who saw the same content in the simultaneous static presentation.

According to these studies, the sequential presentation format may be beneficial as it reduces the cognitive-perceptual demands by providing learners with less information to be processed in WM concurrently and facilitating the integration of information in LTM. In addition, displaying sequentially the components of a system in a defined order can be seen as a form of temporal cueing, thus facilitating the building of well-structured and organized knowledge in LTM (Jamet, Gavota, & Quaireau, 2008). In other words, participants who during the learning phase studied visualizations sequentially would in the test phase retrieve corresponding items in the order in which they appeared (Taylor & Tversky, 1992). Bétrancourt et al. (2001) used a map of a library to compare the effects of sequential and simultaneous static presentation formats. The findings indicated that, although the sequential presentation did not affect learning outcomes, the order of recalling of the map was consistent with the type of sequential presentation used.

However, a number of research studies have shown that the effectiveness of instructional materials is a function of the expertise of the learner. There have been interactions observed between the effectiveness of different instructional formats and levels of learner expertise. The information presentation that is effective for a novice could be ineffective for an expert and vice versa. This interaction is referred to as the expertise reversal effect (e.g., Kalyuga et al., 2003; Khacharem, Zoudji, Kalyuga, & Ripoll, 2013). For example, Blayney, Kalyuga, and Sweller (2010) demonstrated that the effect of sequential presentation in accounting training was influenced by levels of learner expertise. Learners with different levels of expertise viewed either isolated elements presented in a sequential form (e.g., using several less complex intermediate working formulas in spreadsheet-based calculations) or in a concurrent form (using a single complex formula). The results indicated that for novice learners, the sequential presentation was superior to the concurrent presentation. But for more experienced learners, this method did not improve learning because these learners had to cross-reference the sequence of presented simplified elements with their available knowledge of more complex structures, thus using up additional cognitive resources.

The sequential presentation technique has only been investigated with static information. It is yet unknown how this technique would affect learning from complex dynamic presentations involving many interacting elements. This study aims to address this issue by assessing the impact of the sequential presentation technique in learning from animated soccer scenes, and to investigate whether the effectiveness of this instructional design would depend on levels of player expertise. Two forms of presentations were tested: concurrent and sequential. The soccer game activity was chosen to investigate these issues given its dynamic nature and the complex interaction occurring simultaneously between numerous elements (North et al., 2011).

On the basis of the expertise reversal effect, it could be predicted that expert players would benefit more from the concurrent presentation (i.e., they would obtain better recall test scores, need a lower number of repetitions, and invest less mental effort when learning) as their superior knowledge base and domain-specific memory skills acquired through deliberate practice would allow them to deal with the constraints of the concurrent animation. These players were expected to process easily the interacting elements moving at once (i.e., concurrently), since they were already matched to an internal semantic template or schema held in LTM. In contrast, novices would benefit more from the sequential presentation (i.e., perform better, need a lower number of repetitions, and invest less mental effort) because many interacting elements occurring at once may exceed their WM capacity.

**Method**

**Participants**

A total of 48 male players served as participants in the experiment. The 24 experts ($M_{age} = 24.2$, $SD = 1.8$) were all semiprofessional soccer players. They had been playing soccer for an average of 13.2 years ($SD = 2.2$) and trained or played for an average of 11.0 hr ($SD = 3.5$) per week. The 24 novice players ($M_{age} = 23.5$, $SD = 2.7$) knew the rules of the game, but they had never played soccer or any other team ball sport in a club. This requirement was applied to avoid the effects of transfer across sports (e.g., Smeeton, Ward, & Williams, 2004). None of the participants had ever taken part in the present type of experiment. Participants who used to play video games related to team ball sports (e.g., Fifa, Pro-Evolution Soccer, or any equivalent games) were excluded. The participants volunteered to participate and provided informed consent. Approval for this project was granted by the local ethics committee.
The Expertise Reversal Effect for Sequential Presentation

Apparatus

The experiment was conducted using a HP Pavilion dv6 computer. The stimuli were presented on a 250 cm × 200 cm screen from a video projection system (Sony VPL EX120 XGA) placed at a distance of 3 m. The display on the screen was 200 cm × 160 cm, with a 45° viewing angle.

Materials

Two different animated soccer sequences were designed using SimulFoot three-dimensional software. (SimulFoot was developed by researchers from the SimGraph team of the Information Science and Systems Laboratory (LSIS) at Aix-Marseille University.) Each sequence showed the development of a clearly structured counterattack. The structured sequences contained coherent, organized counterattack scenes that put players in conditions likely to be experienced during competition matches. To guarantee that the presented information was a realistic depiction of a soccer playing system and was matched to specific offensive tactical components, the sequences were developed in collaboration with three experienced soccer coaches. Firstly, together with an expert coach, we created two coherent counterattack sequences that involved six players who carried out a rapid tactical combination of play composed of five passes toward the opponent’s court before a shot at goal was taken. During each pass, each player should move in relation to the ball and the teammates’ positions to offer an appropriate solution to the ball carrier. Each pass corresponded to a new stage made up of multiple offensive actions carried out by the players (e.g., moving, position switching, overlapping). The two sequences of 31.5 s and 32.3 s in length were captured from a sideline camera in an elevated position (25°), such that the entire field and all players were visible. This type of presentation allows a concurrent display of the components of the situation (see Figure 1). Secondly, we generated a sequential presentation from each animation (i.e., concurrent presentation). In this version, each stage of play was divided into a set of meaningful chunks composed of two, three, or four players that transited successively and separately from one stage to another (see Figure 2). Finally, another two experienced soccer coaches independently rated on a 9-point Likert scale each sequence in relation to (a) whether the pattern of play corresponded to a structured counterattack soccer scene (0 = very unstructured; 5 = very structured) and (b) whether the chunks presented in each sequence were representative of a meaningful (typical) grouping of players (0 = very nonrepresentative; 5 = very representative). All sequences were rated 4 or above and thus were kept for the experimentation. Note that all coaches (including the first author) were licensed by the French Football Federation and had satisfactory experience at a semiprofessional level (M = 8.42 years, SD = 1.74).

Procedure

The experimental sessions were conducted individually and involved a study phase and a test phase. The experimental sessions lasted no more than 45 min. Before being exposed to the experimental materials, participants were
given a printed outline of the different phases of the study, in which they were informed about the general procedure. The presentation order of the two scenes (i.e., concurrent and sequential) was counterbalanced within subjects. Immediately after having watched either a concurrent or sequential presentation (study phase) players were asked to rate the mental effort invested in studying the scene of play and perform a recall-reconstruction test (test phase).

**Study Phase.** In this phase, the participant was asked to memorize the soccer scenes as accurately and as rapidly as possible. For each presentation, the projection of the scene began as soon as the learner clicked on the “Ready!” button. Participants could not stop the display, but when it was over, they could see it again as many times as desired by clicking on the “Repeat” button (the number of repetitions was registered by the system). When the subjects felt they had learned the scene of play, they had to click on the “End” button.

**Test Phase.** The test phase occurred immediately following the study phase of each presentation type. The participant was asked to perform two successive tasks, as follows. (i) Evaluate the mental effort invested in studying the learning material (“Please indicate how much mental effort did you invest in studying the animation?”) on a 9-point subjective rating scale, ranging from (1) very, very low mental effort to (9) very, very high mental effort (Paas, 1992; Paas, Tuovinen, Tabbers, & Van Gerven, 2003). This self-report measure is widely accepted as a valid and noninvasive method of estimating cognitive load (e.g., Paas, 1992; Paas, Tuovinen, Tabbers, & Van Gerven, 2003; Paas & Van Merriënboer, 1993, 1994; Paas, Van Merriënboer, & Adam, 1994). (ii) Reconstruct the scene of play by drawing it on a sheet of paper that contained an empty soccer field, with the same viewing angle as in the experimental conditions (see Figure 3). The soccer field was divided into five parts. For each part (stage of play), participants were instructed to reconstruct as accurately as possible the position of the six players (with different numbers) in relation to the ball which had been already placed in its correct position. In each part, they had to reproduce (a) the position of the ball carrier, (b) players located in front of the ball (on the left, in the middle, or on the right), and (c) players located behind the ball (on the left, in the middle, or on the right). One point was awarded for each correct placement of a player in the field; no point was awarded for each incorrect placement of a player in the field. The scores could, therefore, range from 0 to 30. An individual naive regarding the hypothesis of the project assured this processes of coding.

**Data Analyses**

A mixed-design ANOVA was used to analyze the data. The between-participants factor was Expertise (expert vs. novice) and the within-participants factor was Condition (concurrent vs. sequential). For all analyses throughout this study, we used $p < .05$ as the criterion for significance, partial eta squared ($\eta^2_p$) values are provided as a measure of effect size for all main effects and interactions, and Cohen’s mean standardized differences ($d$) for post hoc comparisons. Partial eta squared values of .01, .06, and .14 and Cohen’s $d$ values of .20, .50, and .80 represent small, moderate, and large effect sizes, respectively.

The dependent variables were recall performance (0–30), number of repetitions needed to memorize the
scene (unlimited), mental effort invested in studying the scene (1–9), and instructional efficiency (score). Instructional efficiency was calculated using Paas and Van Merriënboer’s (1993) computational approach.

\[
\text{Efficiency} = \frac{(Z_{\text{Recall}} - Z_{\text{Mental Effort}})}{\sqrt{2}}
\]

This measure combines standardized z-scores for the test performance scores with standardized z-scores for the ratings of mental effort associated with studying the materials. According to this definition of relative instructional efficiency, a lower rating of effort combined with higher performance scores would provide evidence of a more efficient learning condition. The denominator \(\sqrt{2}\) is used to make the graphical interpretation of the formula more straightforward by representing the mental effort and performance z-scores in a cross of axes. The relative efficiency at any point on the diagram can be measured as the distance from this point to the line of zero efficiency \((Z_{\text{Recall}} = Z_{\text{Mental Effort}})\).

**Results**

Descriptive statistics for recall accuracy, mental effort, number of repetitions, and learning efficiency for novice and expert participants are presented in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Concurrent</th>
<th>Sequential</th>
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<tbody>
<tr>
<td><strong>Expert</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recall Accuracy</td>
<td>26.79 (1.02)</td>
<td>26.45 (1.31)</td>
</tr>
<tr>
<td>Mental Effort</td>
<td>3.50 (0.93)</td>
<td>4.37 (0.57)</td>
</tr>
<tr>
<td>Number of Repetitions</td>
<td>4.25 (0.67)</td>
<td>4.70 (1.08)</td>
</tr>
<tr>
<td>Learning Efficiency</td>
<td>1.32 (0.55)</td>
<td>0.73 (0.55)</td>
</tr>
<tr>
<td><strong>Novice</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recall Accuracy</td>
<td>21.79 (0.93)</td>
<td>23.29 (1.82)</td>
</tr>
<tr>
<td>Mental Effort</td>
<td>6.04 (1.00)</td>
<td>4.95 (0.69)</td>
</tr>
<tr>
<td>Number of Repetitions</td>
<td>6.58 (0.97)</td>
<td>6.29 (0.85)</td>
</tr>
<tr>
<td>Learning Efficiency</td>
<td>−1.55 (0.55)</td>
<td>−0.50 (0.60)</td>
</tr>
</tbody>
</table>
Recall Accuracy
ANOVA revealed a significant main effect of expertise in recall performance, $F(1,46) = 226.79$, $p < .001$, $\eta^2_p = .83$. Expert participants ($M = 26.62$, $SD = 0.24$) were more accurate than novice counterparts ($M = 22.54$, $SD = 1.06$). There was also a significant main effect of condition, $F(1,46) = 4.72$, $p = .035$, $\eta^2_p = .09$, indicating that participants performed better in the sequential presentation condition ($M = 24.87$, $SD = 2.23$) than in the concurrent presentations condition ($M = 24.29$, $SD = 3.53$). There was a significant interaction Expertise × Condition interaction, $F(1,46) = 11.64$, $p = .001$, $\eta^2_p = .20$. The analyses of simple effects revealed a significant difference for the novices, $p = .001$, $d = 1.04$, and a nonsignificant difference for the experts, $ns$, $d = 0.28$. Thus, whereas the novice participants performed better in the sequential than in the concurrent condition, the expert participants performed at the same level regardless of the condition.

Mental Effort
There was a significant main effect of expertise, $F(1,46) = 91.95$, $p < .001$, $\eta^2_p = .66$, demonstrating that the novice participants ($M = 5.49$, $SD = 0.77$) had to invest more mental effort than the expert participants ($M = 3.93$, $SD = 0.61$). Although there was no main effect of condition, $F(1,46) = 37.17$, $p = .54$, $\eta^2_p = .008$, there was a significant expertise × condition interaction, $F(1,46) = 32.84$, $p < .001$, $\eta^2_p = .41$. The analyses of simple effects revealed significant differences for both the novices ($p < .001$, $d = 1.27$) and experts ($p = .004$, $d = 0.16$). Whereas the novices invested more mental effort in the concurrent condition than in the sequential condition, the experts invested more mental effort in the sequential condition than in the concurrent condition.

Number of Repetitions
ANOVA indicated a significant main effect of expertise, $F(1,46) = 106.40$, $p < .001$, $\eta^2_p = .69$. The novice participants ($M = 6.43$, $SD = 0.20$) needed a significantly larger number of repetitions than the expert counterparts ($M = 4.47$, $SD = 0.31$). There was no significant effect of condition, $F(1,46) = .21$, $p = .320$, $\eta^2_p = .004$; however, there was a significant interaction between expertise and condition, $F(1,46) = 4.25$, $p = .04$, $\eta^2_p = .008$. The analyses of simple effects following the significant interaction found no significant differences in the number of repetitions between the two conditions either for novices ($ns$, $d = –0.31$) or for experts ($ns$, $d = 0.32$).

Learning Efficiency
The data for this analysis are illustrated in Figure 4. The results showed a significant main effect of expertise, $F(1,46) = 363.76$, $p < .001$, $\eta^2_p = .88$, indicating that learning was more efficient for the expert participants ($M = 1.02$, $SD = 0.41$) than for the novice counterparts ($M = –1.02$, $SD = 0.74$). Although there was no significant main effect for condition, $F(1,46) = 3.31$, $p = .07$, $\eta^2_p = .006$, there was a significant interaction between expertise and condition, $F(1,46) = 44.24$, $p < .001$, $\eta^2_p = .49$. Following the significant interaction, the analyses of simple effects revealed a significant difference between the two conditions for both the novices ($p < .001$, $d = 1.82$) and experts ($p < .01$, $d = 1.07$). Whereas for the novices, the sequential presentation was more efficient than the concurrent presentation, for the experts, the concurrent presentation was more efficient than the sequential presentation.

Discussion
The main goal of this study was to investigate the effects of concurrent versus sequential presentation in learning from animated soccer scenes depending on players’ level of expertise. The results supported the predicted interaction between the presentation formats and levels of player expertise (i.e., expertise reversal effect), with the best format of instructional animation being dependent on the levels of learner expertise.

The sequential presentation was more beneficial for novice players (i.e., they attained higher recall performance, invested less mental load, and needed the same number of repetitions). This result is consistent with the previous research using static visualizations that indicated advantages of sequential display over complete display (e.g., Jamet & Arguel, 2008). From the perspective of cognitive load theory, by displaying sequentially the elements of the play, the high intrinsic cognitive load linked to the complexity of the animation was avoided since...
the visual elements were gradually (serially) processed and integrated, resulting in better learning outcomes. In addition, the sequential presentation highlighted different chunks, as well as their display order on the screen, which could facilitate their structuration, categorization, and organization in LTM (Jamet et al., 2008). Finally, we can assume that the animated elements that formed a chunk might stand out against the rest of the display due to their movements (i.e., transition from one stage to another) and thus cause a dynamic contrast (Schnitz & Lowe, 2008) by automatically attracting players’ visual attention (cf. Hillstrom & Chai, 2006; Hillstrom & Yantis, 1994). This could make them more aware of particular changes that occur at a macro level in the animation. However, whether any of these explanations is more plausible or whether it is their combination that makes sequential presentation more effective for novice players is an open question for future research to address.

On the other hand, expert players benefited primarily from the concurrent presentation (i.e., they attained the same recall performance and needed the same number of repetition, but invested less mental effort) because their available knowledge structures allowed them to manage many concurrent interacting elements of information. However, in the sequential presentation, they would need to cross-reference and reconcile their knowledge structures with instructional details that were for them redundant and superfluous. Additional extraneous (unnecessary) cognitive load may therefore be required for such processing, thus increasing WM demands and reducing relative learning outcomes. These findings extend previous research demonstrating that the expertise reversal effect for the sequential presentation method could not only occur when using static presentations (e.g., Blayney et al., 2010), but also when using animations.

The expertise reversal effect demonstrated in the current study fits well with some studies conducted within the frameworks established by the theories of skill acquisition and automaticity (e.g., Anderson, 1987; Fitts & Posner, 1967). According to these studies, training in conditions that require explicit cognitive control and monitoring of the execution of complex sensorimotor skills (e.g., golf putting, soccer dribbling, and baseball batting) could enhance performance of novices but hinder performance of expert counterparts (Beilock, Bertenthal, McCoy, & Carr, 2004; Gray, 2004). In the initial learning phase (cognitive phase), learning and performance of novices are based mostly on declarative knowledge, and the skill execution is supported by a set of unintegrated control structures that are held in WM and attended in a step-by-step manner (Fitts & Posner, 1967). However, with deliberate and repeated practice, experts develop more proceduralized and automated knowledge that operates outside of WM (autonomous phase). As a result, attention to execution at the step-by-step level is thought to disrupt the automated functioning of such skills (Beilock & Carr, 2001).

Some questions remain unanswered and require further research. This study focused on learning from animated soccer scenes presented alone without verbal commentaries that could potentially direct learner’s attention to crucial elements and/or to describe the individual and collective actions in the field. It is unclear whether the current results would be replicated with animations that are accompanied by text or verbal instructions. In addition, this study provided evidence of an expertise reversal effect for the sequential presentation method in learning from soccer visualizations. Naturally, one wonders how well our results generalize to learning materials that are both more and less intrinsically complex, and transfer to other team sports activities or unrelated areas. Finally, in this study, the learner performance was measured using a recall reconstruction test. It would be interesting to investigate whether the sequential presentation method would also improve the learning of tactical skills measured by players’ problem-solving abilities in dealing with novel game situations. Since such skills are likely related to the integrated, concurrent vision of the game situations, using an ordered set of combined sequential and concurrent presentation formats could possibly be the best instructional approach to be used with novice learners (similar to isolated-interacting elements effect in cognitive load theory; Sweller et al., 2011).

On a practical level, these results suggest caution in the use of instructional animations that depict the functioning of a playing system. For novice players, it is more judicious to use animations that sequentially display the components of the play. However, with the increase of expertise in the domain, concurrent animations are recommended to further enhance the constructed schemas. In conclusion, these results provide strong evidence that processing and integrating a visual representation depends not only on characteristics of the visual display, but also on characteristics of learners, especially on their level of expertise. Accordingly, tailoring visual displays to players with differing levels of expertise should be a crucial part in the work of both soccer coaches and multimedia designers.

References
Bétrancourt, M., Bisseret, A., & Faure, A. (2001). Sequential display of pictures and its effect on mental representa-


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