Effect of contextual knowledge on spatial layout extrapolation

Emmanuelle Ménétrier¹ · André Didierjean² · Valérie Barbe¹

Published online: 16 July 2018
© The Psychonomic Society, Inc. 2018

Abstract

Boundary extension (BE) refers to the tendency to remember a previously perceived scene with a greater spatial expanse. This phenomenon is described as resulting from different sources of information: external (i.e., visual) and internally driven (i.e., amodal, conceptual, and contextual) information. Although the literature has emphasized the role of top-down expectations to account for layout extrapolation, their effect has rarely been tested experimentally. In this research, we attempted to determine how visual context affects BE, as a function of scene exposure duration (long, short). To induce knowledge about visual context, the memorization phase of the camera distance paradigm was preceded by a preexposure phase, during which each of the to-be-memorized scenes was presented in a larger spatial framework. In an initial experiment, we examined the effect of contextual knowledge with presentation duration, allowing for in-depth processing of visual information during encoding (i.e., 15 s). The results indicated that participants exposed to the preexposure showed decreased BE, and displayed no directional memory error in some conditions. Because the effect of context is known to occur at an early stage of scene perception, in a second experiment we sought to determine whether the effect of a preview occurs during the first fixation on a visual scene. The results indicated that BE seems not to be modulated by this factor at very brief presentation durations. These results are discussed in light of current visual scene representation theories.

Keywords Visual perception · Scene memory · Context effect · Boundary extension

One of the fundamental conditions for adaptation relies on the ability of the visual system to realize predictions relative to the environment in which an observer is located. The capacity for adaptation has mainly been studied in the field of motion, including the phenomenon known as *representational momentum* (Freyd & Finke, 1984; e.g., Didierjean, Ferrari, & Blättler, 2014; Hubbard, 2005, 2015, for reviews), which refers to the tendency to extrapolate the future trajectory of a moving object (e.g., Hubbard & Bharucha, 1988) or the probable evolution of a moving scene in which the observer is embedded (e.g., Blättler, Ferrari, Didierjean, Van Elslande, & Marmèche, 2010; Thornton & Hayes, 2004). However, the ability to predict has also been observed in a dimension

of the environment complementary to motion: the establishing of the spatial layout of the perceived scene (e.g., Munger, Owens, & Conway, 2005). In this case, the extrapolation process refers to a tendency to overestimate the spatial expanse of a previously perceived scene, a phenomenon known as *boundary extension* (BE; Intraub & Richardson, 1989; e.g., Intraub, 2010, 2012, for reviews).

In natural viewing conditions, drastic physiological limitations prevent the observer from seeing his/her environment at a glance, constraining him/her to scan the environment with head and eye movements. Although the visual field is limited both horizontally and vertically, the visual system seems to have evolved in a manner that “ignores” the spurious boundaries of successive individual views caused by these limitations, by extrapolating a layout that could be present immediately beyond the edges of the perceived views (e.g., Park, Intraub, Yi, Widders, & Chun, 2007). Classical studies such as Intraub and Richardson’s (1989) seminal work have observed boundary extension following the memorization of a series of photographs presented for 15 s each. Memory has generally been tested immediately after scene presentation (see, however, Intraub, Bender, & Mangels, 1992; Intraub & Richardson, 1989, for a 35-min or a 48-h delay) by asking

---

✉ Emmanuelle Ménétrier
emmanuelle.menetrier@univ-angers.fr

¹ Laboratoire de Psychologie des Pays de la Loire UPRES EA 4638, Université d’Angers, Maison de la recherche Germaine Tillion, 5 bis Boulevard Lavoisier, 49045 Angers Cedex 1, France

² Laboratoire de Psychologie EA 3188, Université de Bourgogne Franche-Comté, Besançon, France

participants to draw the previously perceived scenes, recognize the scenes by evaluating their distance relative to the distance in the original photograph, adjust the boundaries of the tested scene, or zoom or reconstruct the original scene (e.g., Chapman, Ropar, Mitchell, & Ackroyd, 2005; Gottesman & Intraub, 2003; Intraub et al., 1992; Intraub, Hoffman, Wetherhold, & Stoebs, 2006). In all the cases, such observations have resulted in unidirectional memory errors, with observers remembering a greater spatial expanse than in the original scene. In this sense, BE is described by Intraub and her colleagues as an error of commission. This type of error refers to memory distortions in which one falsely remembers details, words, or events (e.g., Intraub & Dickinson, 2008).

Although BE can be spontaneously apprehended as a long-term memory phenomenon, as is the case with classical errors of commission (e.g., Dickinson & Intraub, 2008; Roediger, 1996), different studies focusing on BE's time course have shown that it can also be observed with displays simulating visual scanning (i.e., with presentation durations commensurate with an eye fixation—e.g., 250 ms—and retention intervals simulating that of a saccadic eye movement—e.g., 42 ms) or with saccade-contingent paradigms in which the phenomenon is tested after an actual saccade (Dickinson & Intraub, 2008; Intraub & Dickinson, 2008). The rapid occurrence of BE suggests that it is activated at an early stage of scene perception and does not result from an ad hoc extrapolation process. Indeed, BE is deployed during scene understanding, with the detection of layout automatically activating a larger spatial framework (Gottesman & Intraub, 2002). Moreover, these observations suggest that BE may participate in the integration process of the successive eye fixations made on a scene (Dickinson & Intraub, 2008; Intraub & Dickinson, 2008; Intraub, Gottesman, Willey, & Zuk, 1996). Thus, if BE is described as an error relative to the content of a previously perceived scene, it nevertheless presents an important adaptive value insofar as it facilitates the spatial processing of visual scenes by priming visual perception of the upcoming layout (Gottesman, 2011) and permits the observer to make relatively good predictions relative to information that is present just beyond the edges of a view. Furthermore, the activation of conceptual information during scene categorization permits the observer to realize predictions relative to the potential larger spatial context in which the perceived scene takes place (Intraub, 2012).

BE is observed in various experimental situations, including conditions in which one would expect to find relatively good memory, such as with low memory loads (e.g., Intraub & Berkowits, 1996; Munger et al., 2005), memory tests administered immediately following scene presentation (e.g., Dickinson & Intraub, 2008; Intraub & Dickinson, 2008), or a high number of trials (Bertamini, Jones, Spooner, & Hecht, 2005). However, one of the

most striking observations has revealed that BE is not limited to the visual modality. Indeed, this phenomenon has also been generalized to haptic, both with blindfolded sighted participants and with a “haptic expert” (i.e., a young woman blind and deaf since early life; Intraub, 2004). This suggests that the phenomenon is a fundamental aspect of scene representation, in which visual and haptic scene representations are even supported by a unitary representation (Intraub, Morelli, & Gagnier, 2015). Similarly, BE has been observed across the lifespan, as much with 3- or 4-month-old infants as with the elderly (Quinn & Intraub, 2007; Seamon, Schleger, Heister, Landau & Blumenthal, 2002). It has also been observed in disorders implicating perceptual processing based primarily on details rather than on the global structure of perceived scenes, such as in Asperger syndrome (Chapman et al., 2005). All these observations suggest that BE is a robust cognitive phenomenon, detected even after a shift in one's gaze, that withstands the effects of conceptual masking (Dickinson & Intraub, 2008) and occurs even when the observer has previously been informed of the nature of the subsequent memory test (e.g., Intraub & Bodamer, 1993).

Rapid errors of commission such as BE are challenging for traditional cognitive models of visual perception to account for, since these models mainly explain errors in terms of the limited capacity of attention or memory (e.g., Intraub, 2012). Indeed, errors of commission are generally observed in conditions implicating lengthy retention intervals, high memory load, or misleading information, and they are not expected across brief retention intervals (e.g., Intraub, 2012; Intraub & Dickinson, 2008). The rapid deployment of BE led Intraub and her colleagues to develop an alternative model to traditional visual cognitive models, the *multisource model of scene perception* (Intraub, 2010, 2012; Intraub & Dickinson, 2008). Whereas traditional models rely only on visual information to explain visual perception, the multisource model apprehends such perception as an act of spatial cognition. According to this model, visual perception relies on different sources of information, with spatial information at its core. The organizing structure of the model is an egocentric framework that gives the observer a sense of the environment within which he/she is embedded (e.g., the camera viewpoint, in the case of the perception of a photograph). Different sources of information “fill in” this framework, providing a multisource representation: external information with visual information, internally driven information with amodal information (i.e., amodal perception makes it possible to “complete” cropped objects and continues the surfaces and textures just beyond the edges of a view) or conceptual and contextual information (e.g., Intraub, 2012). Conceptual and object-to-context information is automatically activated when the visual system identifies the perceived view as a scene (i.e., as a partial view of a

continuous world; e.g., Gottesman & Intraub, 2002) and generates expectations relative to the surrounding world, enabling the observer to place the perceived view in a larger spatial framework (Intraub, 2012; Intraub et al., 2015). Since visual perception is graded (with less acuity in the peripheral region), visual memory of the scene is less accurate near the boundaries of the view. When remembering a view, the observer may encounter difficulty with discriminating internally generated information (i.e., amodal continuation of cropped objects and surfaces) from visual sensorial information, leading to BE (e.g., Gagnier, Dickinson, & Intraub, 2013; Intraub, 2010, 2012; Intraub & Dickinson, 2008). Indeed, during retrieval, the observer is faced with a multisource monitoring task (Intraub, 2012; Johnson, Hashtroudi, & Lindsay, 1993) in which he/she has to discriminate externally perceived from internally generated information. This results in an extension of the boundaries of the previously perceived view and suggests that BE can be conceptualized as a source-monitoring error (Johnson et al., 1993).

According to the multisource model, top-down expectations derived from conceptual and contextual knowledge play a central role in spatial layout extrapolation (e.g., Intraub, 2012). Paradoxically, although the literature has focused on the role of top-down expectations to account for layout extrapolation, their effect has rarely been tested experimentally (but see Mamus & Boduroglu, 2018; Ménétrier, Didierjean, & Robin, 2017). In the present study, we sought to investigate the effect of contextual knowledge on BE by attempting to determine the effect of prior exposure to a visual source depicting the content beyond the boundaries of the to-be-memorized scene. To induce this kind of knowledge, an adapted version of one of the most commonly used paradigms in research on BE, the *camera distance paradigm*, was used (e.g., Bertamini et al., 2005; Gagnier & Intraub, 2012; Intraub et al., 1992). In the classical version of the paradigm, observers have to memorize to the best of their ability a variable number of photographs (from seven to 20; e.g., Intraub & Berkowitz, 1996; Intraub & Richardson, 1989) by paying as much attention to the objects as to the background of the presented stimuli. The photographs generally remain on screen for 15 s, to allow for in-depth processing of the visual information. After a varying retention interval (from immediately after to a 48-h delay; e.g., Gagnier & Intraub, 2012; Intraub et al., 1992; Intraub & Richardson, 1989), participants are informed that they will see the same scenes as the previously memorized ones, but that some of these scenes have been modified in terms of distance. They then have to rate on a five-point scale whether the newly presented scenes are closer up, farther away, or at the same distance as the original ones. In this paradigm, BE occurs when a test stimulus (i.e., a stimulus that is strictly the same in the memorization and recognition phases) is rated as being closer up, indicating that the

observer's memory includes extended boundaries. This pattern of results is observed when close-up versions of the scenes are presented during the memorization phase, with wide-angle versions leading to weak extrapolation or to no directional distortion at all (e.g., Dickinson & Intraub, 2008). In a similar manner, distractors (i.e., scenes presented in different versions in the two experimental phases) are rated as being more similar when a scene is presented in a close-up version during memorization and in a wide-angle version during recognition, rather than in the inverse order. In the present research, we preceded the memorization phase with a preexposure phase, during which each of the to-be-memorized scenes was presented in a larger spatial framework. Thus, an important difference of this paradigm from classic research on BE phenomenon and from the way in which the phenomenon is conceptualized through the multisource model relies on the fact that, in the present research, the participants did not have to discriminate between externally perceived and internally generated information during recognition (i.e., reality-monitoring task), but instead had to discriminate between two sources of external information—that is, the visual information perceived during the preexposure phase and during encoding (i.e., an external–external source-monitoring decision).

In the present research, we attempted to determine how prior exposure to a visual source depicting the to-be-memorized scene in a larger spatial framework influences spatial layout extrapolation. This question was addressed from a time-course perspective, in order to examine how exposure duration affects the external–external source-monitoring process involved in such a situation. Indeed, this seems interesting because both BE and context effects are known to occur at an early stage of scene perception—that is, during the first fixation realized on a scene (e.g., Biederman, Rabinowitz, Glass, & Stacy, 1974; Dickinson & Intraub, 2008; Intraub, 2012). For instance, by breaking the structural relationships naturally maintained by the elements of a visual scene (i.e., a jumbling process; Biederman, 1972), Biederman et al. (1974) demonstrated that contextual information is available early on to disrupt object perception. In the same way, Biederman, Mezzanotte, and Rabinowitz (1982) showed that object identification is disrupted (i.e., identified more slowly and with more errors) when the object appears in a scene that is correctly formed but that violates the relational rules that link the object to its context. More recently, Davenport and Potter (2004) showed that semantic consistency affects both object and background perception at presentation durations as brief as 80 ms, leading the authors to conclude that an object and its surroundings are processed interactively. Thus, the issue was to establish whether visual context can also exert an effect on spatial layout extrapolation during presentation durations commensurate with an eye fixation. In this context, we presented two experiments with long and short scene exposures

(15 s and 250 ms), where the long exposures allowed a depth of processing of the visual information that was not possible with brief scene presentations.

Since the effect of visual context had not been studied to date, it was difficult to predict the nature of the effects likely to be observed. In point of fact, opposite predictions, based on the external–external source decision framework (Johnson et al., 1993), could be made. First, it seemed possible that, during the memorization phase of our experiments, the larger spatial context perceived in the preexposure condition—which will be referred to as the *preview*—would be activated. This would result in difficulty, during recognition, discriminating the information perceived during the memorization phase from the contextual information acquired during the preexposure phase. Consequently, we would observe enhanced boundary extension in the preexposure as compared to the control condition. Alternatively, since BE is known to occur in the first view of a scene—that is, in situations that elicit expectations about the surrounding context that the current view only partially reveals (e.g., Intraub, 2012)—we could suppose that spatial layout extrapolation would be weaker in the preexposure condition. Since the observer would have knowledge relative to the surrounding space, it would be reasonable to expect decreased BE among these participants. Moreover, since BE occurs early in scene perception (e.g., Intraub et al., 1996), a second objective would be to determine when a possible effect of a preview intervened.

Experiment 1

In Experiment 1 we sought to study the effect of contextual knowledge on BE with a presentation duration permitting in-depth processing of the visual scene during encoding (i.e., 15 s). In this experiment, the camera distance paradigm was adapted in order to induce contextual knowledge relative to the elements present outside the boundaries of the to-be-memorized photographs. For half of the participants, memorization was preceded by a preexposure phase, during which participants had to attentively observe each of the to-be-memorized photographs presented in a larger spatial framework (i.e., a very wide-angle version of the scene).

Consistent with Johnson et al.'s (1993) external–external source decision framework, opposite predictions could be made. As was previously described, we could, on the one hand, suppose that the larger spatial context perceived in the preexposure condition would be activated during memorization. This might lead to greater difficulty in discriminating, during recognition, the information actually perceived during the memorization phase from the contextual information acquired during the preexposure phase. We would therefore expect to find enhanced BE in the preexposure condition, in comparison to the without-preexposure condition. On the

other hand, since BE is known to occur for the first view on a scene (e.g., Dickinson & Intraub, 2008), it is possible that the need for spatial layout extrapolation would be weaker in the preexposure condition, resulting in reduced BE in these participants.

Method

Participants

Fifty undergraduate students (35 females, 15 males) from the University of Bourgogne–Franche-Comté (Besançon, France), whose average age was 21 years 9 months ($SD = 5$ years, range = 17–51), took part in the experiment in order to obtain course credit. They presented normal or corrected-to-normal vision. None of them were aware of the objectives of the study.

Apparatus

The participants were tested individually using a 15-in.-screen MacBook Pro (2006) portable computer, and the experiment was run with the PsyScope software (Cohen, MacWhinney, Flatt, & Provost, 1993). During the experiment, participants were seated approximately 50 cm from the computer screen.

Stimuli

A total of 40 pictures were created for the purposes of this experiment. They depicted 16 scenes with different extents: very wide-angle (16 photographs), wide-angle (16), and close-up (8; see Fig. 1 for an example). The wide-angle and close-up versions of the scenes were created by cropping the very wide-angle version by a mean of 76.5% ($SD = 11.7\%$) and 91.7% ($SD = 4\%$), respectively.

Thus, there were 16 core photographs from which the other versions of the scenes were created. These 16 pictures represented very wide-angle versions of everyday scenes displaying a central object photographed in a natural setting. These very wide-angle scenes were presented during the preexposure phase to half the participants, in order to induce knowledge relative to the larger spatial context in which the object was placed; these photographs showed a significant amount of background information and detail (see Fig. 1). The mean surface occupied by the central object in these scenes was approximately 3.2% ($SD = 2.1\%$).

Half of the scenes were used as test stimuli; that is, the same photographs were used during the memorization and test phases of the experiment. Previous research had demonstrated an effect of view type, with BE being greater in the case of close-ups than of wide-angle views of the same scenes, the latter of which generated either weak BE or no BE at all (e.g., Gottesman & Intraub, 2002; Intraub & Dickinson, 2008). We

Fig. 1 Examples of photographs presented during the experiments. The photograph on the left depicts an example of a scene presented during the preexposure phase, in which each of the to-be-memorized central objects was presented in a very large spatial setting in order

to induce contextual knowledge. The pictures in the middle and on the right, respectively, depict a wide-angle and a close-up version of the same scene presented during memorization and test.

therefore used a version of the camera distance paradigm (e.g., Intraub et al., 1992) in which only close-up versions of the scenes were tested, permitting us to obtain a more sensitive BE test (Dickinson & Intraub, 2008, Exp. 1; Intraub, Daniels, Horowitz, & Wolfe, 2008, Exp. 3; Munger & Multhaup, 2016). For these stimuli, approximately 40.6% ($SD = 11\%$) of the mean surface was covered by the central object. These trials are referred to as *CC trials*.

The other half of the stimuli were distractors; that is, their view type differed across the two phases of the experiment. The stimuli that had appeared in a close-up version during the memorization phase were presented in a wide-angle version during the test phase (referred to as *CW trials*), and vice versa for the photos originally presented in a wide-angle version (referred to as *WC trials*). This led to the creation of a close-up and a wide-angle version for each of these stimuli, in which the central object covered, on average, 41.8% ($SD = 7.1\%$)¹ of the total surface of the scene in the close-ups versions, and 11.4% in the wide-angle versions ($SD = 3.8\%$).

Thus, 16 very wide-angle views were presented during the preexposure phase, and 12 close-ups and four wide-angle views were presented during the memorization and recognition phases. An additional photograph with the same characteristics as the close-up stimuli presented during memorization was used as an example during the familiarization phase.

During the experiment, the photographs were screen-centered; they appeared on a white background, and their dimensions were 14.2×10.1 cm, with a visual angle of approximately $16.3^\circ \times 11.5^\circ$.

Procedure

The participants were randomly assigned to either the preexposure or the without-preexposure condition. As was

previously mentioned, we used an adapted version of the camera distance paradigm, which classically comprises a memorization phase and a recognition test.

Preexposure For half of the participants, the memorization phase was preceded by a preexposure phase, during which each of the 16 to-be-memorized photographs was presented in a very wide spatial framework, to induce knowledge relative to the object's environment (i.e., the preview pictures). The participants were asked to observe each photograph as attentively as possible. There was no specific instruction asking them to memorize these pictures. During this phase, the presentation of each photograph was preceded by a 600-ms fixation point, and the stimuli remained on screen for 15 s. This duration was chosen in order to allow in-depth processing of the object's environment. The stimuli were presented randomly and each presentation was followed by a blank screen, so that the interstimulus interval was 2 s.

Memorization Preexposure was immediately followed by the memorization phase, during which each of the previously observed scenes appeared in either a close-up version (test photos and half the distractors) or a wide-angle version (half the distractors), referred to as the *stimulus views*. The view type of the distractors was counterbalanced across participants. The photographs appeared randomly and remained on screen for 15 s, as in classical boundary extension tasks. The observers had to memorize each photograph to the best of their ability, paying as much attention to the main object as to its background. A 600-ms fixation point preceded each photograph, and a 1,400-ms blank screen appeared after each stimulus.

Recognition test Immediately after the memorization phase was completed, participants were given a recognition test, during which the previously memorized photographs

¹ Mann–Whitney and Levene tests indicated equivalent mean surfaces and equivalent variances for the test and distractor close-ups, with, respectively, $U = 36.00$, $p = .721$, and $F = 0.735$, $p = .406$.

reappeared in a random order. Participants were informed that they were going to see the same scenes as before, but that some of them might have been modified in terms of distance. Using a five-point scale (ranging from -2 to 2), participants compared the scope of each of the new scenes to the original. They were told that the newly presented photographs might be exactly the same as the original (0 value of the scale), a little closer up (-1), much closer up (-2), a little farther away (1), or much farther away (2). The participants also had to report their confidence ratings for each response by choosing from among the following options: *sure*, *pretty sure*, *not sure*, and *I don't remember this picture*. There was no time limit for them to validate their answers.

For participants assigned to the without-preexposure condition, the experiment began at the memorization phase and was exactly the same as in the preexposure condition.

In both conditions, the participants perceived a total of eight CC trials, four CW, and four WC trials. Furthermore, memorization was preceded by a familiarization phase, during which a photograph was presented in order to allow the observers to familiarize themselves with the types of stimuli and their presentation duration.

Results

Globally, participants reported being *sure* of their responses in 50.9% cases, *pretty sure* in 36.5%, and *not sure* in 12.4%. They reported having forgotten a picture in 0.3% of cases.

Test pictures analysis (CC trials)

To determine whether memory distortion had occurred, we computed the .95 confidence intervals associated with each mean (e.g., Gagnier & Intraub, 2012; Gottesman & Intraub, 2002), with a rating equivalent to 0 referring to the absence of directional distortion, a significant negative value indicating BE, and a significant positive value indicating boundary restriction (BR). When we computed the analyses on all trials (except forgotten pictures), we observed significant BE in both the preexposure condition (mean boundary rating = -0.13 , $SD = 0.27$, upper limit of the confidence interval [UL] = -0.02 , lower limit of the confidence interval [LL] = -0.24) and the without-preexposure condition (mean boundary rating = -0.29 , $SD = 0.24$, UL = -0.19 , LL = -0.38). A Student t test revealed a significant effect of preexposure, $t(48) = -2.15$, $p < .05$, $d = 0.63$. However, when we computed the analyses on high-confidence trials only, our results revealed a different pattern, in which we observed significant BE in the without-preexposure condition, but no directional memory distortion in the preexposure condition. The corresponding mean boundary ratings are represented in Fig. 2a. As we had previously found, a Student t test revealed a significant effect of preexposure, $t(48) = -2.37$, $p < .05$, $d = 0.67$.

To determine whether the reduction of BE observed for CC trials in the preexposure condition was the result of better memory for the boundaries of the perceived images, we compared, *a posteriori*, the mean percentage of correct responses observed for each condition (cf. Table 1 for the corresponding

Fig. 2 (a) Mean boundary ratings observed in test trials (CC) as a function of the experimental condition. (b) Mean boundary ratings obtained for distractors (CW and WC trials). (c) The distractors' asymmetry with the mean boundary ratings in absolute values.

The error bars represent the .95 confidence intervals. All these graphs depict results observed for high-confidence trials (*sure* and *pretty sure* responses).

Table 1 Mean percentages of correct responses and of error type (BE vs. BR) observed for each condition, as a function of confidence rating (SDs in parentheses)

		All Confidence Trials			High-Confidence Trials		
Response		Correct	BE	BR	Correct	BE	BR
Condition	With pre-exposure	71 (19.34)	61.73 (38.86)	30.27 (35.33)	76.38 (20.21)	50.33 (45.29)	25.67 (37.88)
	Without pre-exposure	69.5 (20.12)	84.34 (33.36)	7.67 (21.77)	72.38 (23.35)	75.00 (43.30)	5.00 (20.41)

percentages). Because analyses revealed the same pattern of results when they were computed on all trials and only on high-confidence trials, we decided to report only the latter observations. A Student *t* test revealed equivalent mean percentages of correct responses, $t(48) = -0.65$, n.s., indicating equivalent performance on the recognition test. Moreover, the mean percentages observed for errors (BE, BR) were analyzed with a 2×2 (Experimental Condition × Error Type) mixed-design analysis of variance (ANOVA) on the participants' mean percentages observed for BE and BR responses (cf. Table 1). We observed an effect of error type, $F(1, 48) = 28.05$, $p < .001$, $\eta_p^2 = .37$, indicating that the participants globally made more BE than BR errors; no effect of condition, $F < 1$; and a significant interaction between these two variables, $F(1, 48) = 6.43$, $p < .05$, $\eta_p^2 = .12$. Student *t* tests conducted *a posteriori* indicated that the participants assigned to the preexposure condition made more BR errors than did the participants assigned to the control condition, $t(48) = -2.40$, $p < .05$, $d = 0.68$.

Distractors analysis (CW and WC trials)

As with the test pictures, these analyses were run twice, on all trials (except forgotten pictures) and then on high-confidence trials only. These analyses led to different patterns of results. To determine whether the classical response asymmetry associated with BE had occurred, we computed a 2×2 (Experimental Condition × View Type) mixed-design ANOVA on participants' mean boundary ratings. When the analyses were run on all confidence ratings, the results indicated an effect of view type, $F(1, 48) = 1,351$, $p < .001$, $\eta_p^2 = .97$; no effect of experimental condition, $F < 1$; and no significant interaction between these two variables, $F(1, 48) = 1.05$, n.s. These observations suggest that the observers used the scale correctly and had been able to discriminate close-up versions from wide-angle versions of the same scene. When the analyses were computed only on high-confidence trials, we observed a different pattern of results, indicating an effect of view type, $F(1, 48) = 1,913$, $p < .001$, $\eta_p^2 = .98$; no effect of experimental condition, $F < 1$; and a significant interaction between these two variables, $F(1, 48) = 6.28$, $p < .05$, $\eta_p^2 = .12$. A series of Student *t* tests revealed effects of view type for both the without-preexposure and the preexposure conditions (all $ps < .001$), but only a tendency toward an effect of

experimental condition for CW ($p = .07$) and WC ($p = .09$) trials. The mean boundary ratings observed for CW and WC trials are presented in Fig. 2b.

We completed these results by carrying out a similar analysis on the absolute values observed for the distractors (e.g., Intraub et al., 2008; cf. Fig. 2c). To determine the absolute values of the WC trials, we multiplied the mean boundary ratings observed by -1 (Czigler, Intraub, & Stefanics, 2013). When we undertook the analyses on all confidence ratings, a mixed model 2×2 ANOVA with experimental condition (preexposure, without preexposure) as a between-subjects factor and view type (CW, WC) as a within-subjects factor showed no effect of view type, $F(1, 48) = 2.16$, n.s.; no effect of experimental condition, $F(1, 48) = 1.05$, n.s.; and no significant interaction between these two variables, $F < 1$. As before, the analyses revealed a different pattern of results when they were computed on high-confidence trials only. Indeed, we observed an effect of view type, $F(1, 48) = 4.91$, $p < .05$, $\eta_p^2 = .09$; an effect of experimental condition, $F(1, 48) = 6.28$, $p < .05$, $\eta_p^2 = .12$; and no significant interaction between these two variables, $F < 1$. These results indicate that the response asymmetry characteristic of BE occurred in spite of a weak effect size in the absolute-value analysis of view type.

Discussion

The observations obtained in this first experiment indicated an effect of preview on spatial layout extrapolation, which resulted in decreased boundary extension on CC trials when observers had previously been exposed to the larger spatial context in which the to-be-memorized scenes took place. This effect even led to an absence of significant directional distortion when we based our analyses on high-confidence-rating responses only. To determine whether the decreased boundary extension observed for CC trials in the preexposure condition resulted from better encoding of the boundaries of the memorized scenes, we compared the mean percentages of correct responses observed for different conditions. The results indicated equivalent mean percentages of correct responses, suggesting that participants' memory was as accurate in the without-preexposure as in the preexposure condition. However, the analyses also revealed that the nature of the errors changed, in that the

participants assigned to the preexposure condition made more boundary restriction errors, leading to the reduction of boundary extension. These observations suggest that the visual system has less need of prediction in cases in which the observer has knowledge of the larger spatial context in which the perceived scene is located. This will be discussed in more detail in the General Discussion section.

A second observation that needed further development was the absence of a view-type effect (CW vs. WC) observed for distractors when the analyses were computed on absolute values (i.e., all confidence ratings). This is a surprising pattern of results, in that it is diagnostic of BE (e.g., Intraub & Dickinson, 2008): Observers usually find that CW trials are closer to 0 than WC trials. However, a significant effect of view type emerged when the analyses were computed on high-confidence ratings only, albeit with a very weak effect size ($\eta_p^2 = .09$). Indeed, this effect size was smaller than that observed by Intraub and her colleagues, who found, for example, effect sizes of $\eta_p^2 = .28$ (Dickinson & Intraub, 2008, Exp. 2) or $\eta_p^2 = .48$ (Intraub & Dickinson, 2008, Exp. 1). This might be explained by the fact that the differences between our two scenes were sometimes highly salient. Indeed, due to the visual characteristics of the very wide-angle versions, some of the wide-angle versions revealed visual details that were not visible in the close-up version of the same scene. For example, the wide-angle version of one of our scenes depicting sandals on a carpet showed some of the floor around the carpet, whereas the close-up version of the same scene did not. This might have led participants to more frequently select the extreme values of the rating scale, as the high mean boundary ratings observed for CW trials suggest (see Fig. 2c). This hypothesis was tested in Experiment 2.

In conclusion, the observations realized in this first experiment suggest that the visual system has less need for prediction when the observer has knowledge of the larger spatial context in which the perceived scene is located. Moreover, because an abundance of literature has shown that the effect of context occurs at an early stage of scene perception (e.g., Biederman et al., 1982; Biederman et al., 1974), one question that arises is to determine whether a preview exerts an effect on spatial layout extrapolation with brief scene exposures. This question was also addressed in Experiment 2.

Experiment 2

Different studies have shown that the semantic category to which a perceived scene belongs is extracted in the first 100 ms following a scene's appearance (e.g., Biederman et al., 1974; Potter, 1976), and that the effect of context on scene perception occurs during the first fixation within a scene—facilitating, for instance, object identification with presentation durations as brief as 150 ms (Biederman et al., 1982), or

even 80 ms (Davenport & Potter, 2004). Since spatial layout extrapolation is deployed during the first fixation of a scene (e.g., Intraub & Dickinson, 2008), one question is whether a preview could influence BE with scene exposures commensurate with the duration of an eye fixation (i.e., 250 ms). To answer this question, we adapted the methodology used in Experiment 1 to very brief presentation durations (i.e., 250 ms). Since BE is known to occur during the first view of a scene (e.g., Dickinson & Intraub, 2008), the need for prediction would be weaker in the preexposure condition. For this reason, it seemed reasonable to expect, and in accordance with the observations made in Experiment 1, a reduction in BE if there were an effect of preview on spatial layout extrapolation with such presentation durations.

The second objective of this experiment was to determine whether the atypical pattern of results observed for distractors (i.e., the absence of a view-type effect when the analyses were computed on all confidence ratings, and the weak view-type effect size observed when the analyses were computed on high-confidence trials only) on absolute values resulted from the visual characteristics of the distractor stimuli. Indeed, due to the contingencies of the very wide-angle version of some of our visual scenes, some wide-angle versions of the distractor scenes revealed details that were absent from the close-up scenes, making the differences between the two versions highly salient. The presence of additional details in the wide-angle versions of the scenes might have led participants to respond more frequently with the extreme values of the rating scale, resulting in very close mean boundary ratings between the CW and WC trials. We tested this hypothesis by reducing the differences between the two versions of the distractor scenes.

Method

Participants

The participants were 44 undergraduate students (36 females, eight males) from the University of Angers (France). Their mean age was 21 years 2 months ($SD = 4$ years 4 months; range = 18–35) and their participation enabled them to obtain a course credit. They had a normal or corrected-to-normal vision. No participant was aware of the objectives of the research, and none had previously participated in Experiment 1.

Stimuli

The stimuli were the same as in Experiment 1. However, the differences between the close-up and wide-angle versions of the distractors were reduced in order to limit the amount of additional detail in the wide-angle version of the scene (cf. Fig. 3 for an example). In this experiment, the central objects of the wide-angle version of the distractors covered,

Fig. 3 Close-up version of a scene (top) and the corresponding wide-angle versions used in Experiment 1 (bottom left) and Experiment 2 (bottom right).

in mean, approximately 28.5% ($SD = 5\%$) of the total surface of the scene. Two additional stimuli were presented during practice trials.

Procedure

The participants were randomly assigned to either the preexposure or the without-preexposure condition. In the preexposure condition, the memorization and test phases were preceded by the same preexposure phase as in Experiment 1, in which the photographs remained on the screen for 15 s, whereas the without-preexposure condition began immediately with the memorization and test phases.

Memorization and test phases The procedure was the same as in Experiment 1; the only difference were that the task was adapted to very brief presentation durations. Since each scene remained on screen for 250 ms, the memory of each was tested immediately after its disappearance (see, e.g., Intraub & Dickinson, 2008). Each trial was initiated by a 600-ms fixation point and was followed by the photograph, which remained on screen for 250 ms. The photographs were then followed by a 1,000-ms visual noise mask. A yellow (500 ms) and then a red (500 ms) central fixation cross appeared on the mask, and participants were asked to maintain their gaze on it for as long as it remained on the screen. The test image appeared immediately afterward, and participants were asked to rate its scope in comparison to the scope of the briefly glimpsed photo, in the same way as in Experiment 1. No time limit was given to validate their response. Participants were then asked to indicate their

confidence rating on the same scale as in Experiment 1, with the only difference being that the last option, *I don't remember this picture*, was replaced by a *random-response* option. This seemed more effective in understanding random responses given after viewing a picture for very brief presentation durations and responding 1 s after the picture had been viewed. In the two experimental conditions, this phase of the experiment was preceded by two practice trials, run in order to familiarize the participants with the task.

Results

Globally, the participants reported being *sure* of their answers on 30% of the trials, *pretty sure* on 40%, and *not sure* on 23%. They declared a “random” answer on 7% of the trials. As before, the analyses were conducted across two periods; the first one included all confidence trials (except the random answers), whereas the second included high-confidence trials only (*sure* and *pretty sure* responses).

Test pictures analysis (CC trials)

When we computed the analyses on all trials, we observed significant BE in both conditions. However, the score of one participant assigned to the preexposure condition was withdrawn from the analyses due to an aberrant BE score (>3 SD s beyond the mean), leading to a total of 21 participants in the preexposure condition. This led to the following results: in the preexposure condition, mean boundary rating = -0.32 , $SD = 0.37$, $UL = -0.15$, $LL = -0.49$; in the without-preexposure condition, mean boundary rating = -0.41 , $SD = 0.36$, $UL = -$

0.25, $LL = -0.57$. A Student t test revealed no significant effect of preexposure on CC trials, $t(41) = -0.76$, n.s. No outlier was detected when we conducted the analyses on the high-confidence trials only, but the data of one participant assigned to the preexposure condition were lost, since this participant systematically gave random responses or was unsure of his/her responses. The mean boundary ratings observed in each condition are shown in Fig. 4a. We observed a pattern of results similar to the one found before: The preexposure and control conditions both yielded BE, and there was no significant effect of preexposure, $t(41) = -0.45$, n.s.

Distractor analysis (CW and WC trials)

Since the patterns of results observed on all trials and on all confidence trials were similar, we decided to focus only on the latter (see Fig. 4b). However, the data of two participants who systematically gave random responses or reported being unsure of their responses were not considered. One of these participants was assigned to the preexposure condition, and the other to the without-preexposure condition, leading to 21 participants in each condition. A mixed-model 2×2 ANOVA computed on the participants' mean boundary ratings (all trials), with experimental condition (preexposure, without preexposure) as a between-subjects variable and view type (CW, WC) as a within-subjects variable, revealed an effect of view type, $F(1, 40) = 377$, $p < .001$, $\eta_p^2 = .90$; no effect of condition, $F < 1$; and no significant interaction between these two variables, $F(1, 40) = 3.90$, n.s. As previously, these results indicated that the observers had used the scale correctly

and had been able to discriminate between close-up and wide-angle versions of the same view.

The same analyses computed on the absolute values revealed the same pattern of results in all trials and in the high-confidence trials. Consequently, only the results observed for the latter analysis are presented (see Fig. 4c). As previously, the analyses computed on high-confidence trials excluded the data of the two participants mentioned above. The analyses revealed an effect of view type, $F(1, 40) = 27.00$, $p < .001$, $\eta_p^2 = .40$; no effect of condition, $F(1, 42) = 3.90$, n.s.; and no interaction between these two factors, $F < 1$. Taken together, these observations indicate that the response asymmetry typical of BE occurred.

Discussion

Since an abundance of literature has demonstrated that the effect of context occurs at an early stage of scene perception (e.g., Bar, 2004), this second experiment was conducted to determine whether the effect of a preview on BE could occur during the first fixation realized on a scene. The findings in this second experiment showed no effect of preview on BE when the to-be-memorized photographs were presented for 250 ms. This pattern of results was observed in both CC and CW/WC trials.

The second objective of this experiment was to determine whether the absence of a view-type effect observed in CW and WC trials when the analyses were computed on absolute values resulted from highly salient differences between the close-up and wide-angle versions of our scenes. To test this

Fig. 4 Mean boundary ratings observed in Experiment 2 with test trials (CC), for each experimental condition (a), and for distractors (b, c). The error bars represent the .95 confidence intervals. All

these graphs depict results observed for the high-confidence trials (*sure* and *pretty sure* responses).

hypothesis, we reduced the differences between the two versions of our scenes. The results indicated both an effect of view type and effect sizes closer ($\eta_p^2 = .40$) to those observed by Intraub and her colleagues (e.g., Intraub & Dickinson, 2008, Exp. 1, $\eta_p^2 = .48$ on all confidence ratings).

The observations made in this second experiment are discussed in the General Discussion section.

General discussion

The aim of the present research was to study the effect of contextual knowledge on spatial layout extrapolation. This question was motivated by the fact that, according to Intraub's multisource model of scene perception (Intraub, 2010, 2012; Intraub & Dickinson, 2008), conceptual and contextual knowledge play a central role in the generation of predictions relative to the larger spatial context in which a scene takes place. In the present study, however, the effect of contextual knowledge was not addressed by activating top-down expectations generating scene construction, but with visual representations that were previously induced by presenting each of the to-be-memorized photographs in a wider spatial framework (i.e., a very wide-angle version of the scene). This question was dealt with using two experiments that examined the effect of a preview from a time-course perspective, with both long and short scene exposures.

The first experiment was aimed at determining the effect of a preview on spatial layout extrapolation with long scene exposure. In this experiment, each of the to-be-memorized scenes was presented for durations allowing an in depth processing of the visual information (i.e., 15 s). The results indicated an effect of preexposure, illustrated by a reduction of BE when the observer had knowledge of the larger spatial context in which the scene took place. This effect was also illustrated by the disappearance of BE when the analyses were computed on high-confidence trials only. Although it seemed plausible to expect enhanced spatial layout extrapolation due to memory for the preview pictures, the absence of increased BE can be put into perspective by recent research by Munger and Multhaup (2016), in which the authors attempted to enrich the surrounding top-down space via cross-modal or visual elaborations. To do so, they presented different imagery tasks during which the participants were invited to imagine the additional sounds, smells, tastes, or surrounding visual information associated with visual scenes they had to memorize. Whereas the authors expected to find increased BE in imagination conditions, they observed no effect of imagery on spatial layout extrapolation. This result is also supported by the fact that sound does not appear to interfere with BE. Indeed, by pairing photographs with music or with sounds evoking a larger spatial context, Gagnier (2010; see also Intraub et al.,

2015, for a description of these experiments) showed that BE is not affected by auditory information.

Although such research has reported no effect of imagination or of an additional auditory source of information, previous exposure to sources of information in the same sensory modality seems to influence BE when the exposure durations allow in-depth processing of the visual source. In the present study, this effect may have arose because these two sources of information were highly confusable, in that they depicted the same scene from different distances, revealing more or fewer details. Thus, the reduction in BE observed in our experiment can be explained by the visual system working to understand the surrounding world of a partially revealed view (e.g., Gagnier et al., 2013), leading to spatial layout extrapolation. We could assume that when an observer has knowledge relative to the larger spatial context in which a partial view takes place, the need for spatial layout extrapolation would be less significant, causing decreased BE. Similar effects are observed when a view depicts a wide-angle version of a scene, leading to weak BE or to no directional error at all (e.g., Intraub et al., 1992; Intraub & Dickinson, 2008).

Nevertheless, the attenuated BE observed in the preexposure condition did not result from a better encoding of the perceived scenes, as revealed by the mean percentages of correct responses observed for each condition. The results indicate that the nature of errors made changes depending on the experimental condition: the observers who had previously perceived the preexposure condition made more BR errors than those who had not. Although further research will be needed to determine the mechanisms responsible for this effect, Gagnier et al. (2013) also observed decreased BE when participants were informed of the nature of the subsequent memory test. By studying oculomotor behavior, the authors observed that the reduction in spatial layout extrapolation reported was related to the amount of attention allocated to the boundary regions of the stimulus scenes, which were fixated earlier, longer, and more frequently. In the present study, however, the reason for the higher rate of BR errors reported in the preexposure condition, may be that the reduction of BE we observed relies on different mechanisms.

Thus, an alternative hypothesis is that more attention was paid to the central aspects (i.e., the central objects, previously perceived in a larger spatial framework) of the scenes during encoding, at the expense of peripheral regions. This may have provided a narrowed focus of attention that may have restricted the visual field (i.e., making the perceived pictures smaller than they really were) and/or visual scanning, leading to decreased BE. According to the source-monitoring framework (Johnson et al., 1993), during recognition, memory for the preview picture may have provoked a source memory error resulting from difficulty in discriminating between boundaries of the mentally restricted area and the real boundaries of the scene. However, such a hypothesis should be considered with

caution: because of the long scene exposure (15 s), it is unlikely that participants focused exclusively on the central portion of the pictures.

Another explanation would be that the participants would have made the connection between the preview pictures and the stimulus views, realizing that the latter are more close-up versions of the preview pictures. Thus, according to source monitoring theories (e.g., Johnson et al., 1993), they may have been engaged in a series of metacognitive processes, leading them to adopt stricter criteria for boundary judgment. This would have led them to underestimate the expanse of the memorized scenes, resulting in more BR errors in the preexposure condition.

A last explanation that might account for the reduction/absence of BE observed in the preview condition of Experiment 1 is that, during recognition, the observers would have been engaged in a spatial rescaling process allowing them to mentally place the stimulus view in the context of the preexposure view. To make the spatial scales of the two views match, it is possible that the observers would “zoom in” their memory of the preexposure picture, in a way analogous to imagining themselves much closer to the scene. This would have led them to remember the stimulus view as being closer up than it actually was, resulting in more boundary restriction errors. Such an effect seems similar to the predicted effect of representational momentum (RM) on memory for spatial expanse in approach sequences, as in studies aimed at determining whether BE and RM were related phenomena (DeLucia & Maldia, 2006; Munger et al., 2005). These studies are commented on below.

Since spatial layout extrapolation and context effects are deployed during the first fixation on a scene (e.g., Biederman et al., 1982; Biederman et al., 1974; Intraub & Dickinson, 2008), we sought to determine, in a second experiment, whether the effect of a preview on spatial layout extrapolation manifests itself during the first fixation realized on a visual scene. We thus adapted our methodology to very brief presentation durations as the scenes remained on screen for only 250 ms, and were tested immediately afterward (e.g., Dickinson & Intraub, 2008). Contrary to the observations made in the first experiment, we obtained no effect of preview on spatial layout extrapolation as the results indicated equivalent mean boundary ratings regardless of whether the observer had knowledge of the larger spatial framework in which the memorized scenes took place. This second experiment can be linked to a study by Munger, Owens, and Conway (2005) who sought to determine whether BE and RM were related phenomena (see also DeLucia & Maldia, 2006). To do so, observers perceived approach sequences depicting an induced motion of the self and designed in a way to elicit RM. Although the authors concluded that BE and RM are independent processes, they also observed that BE was globally stronger than RM in approach sequences.

Although the objective of Munger et al.’s (2005) study was not to determine the effect of the larger spatial context previously perceived regarding the memories of the boundaries of the scene, the authors interpreted BE in approach sequences as the inclusion of part of the wide-angle view into the memory for the final close-up view of the approach sequences (see also Ménétrier et al., 2017). However, the effect of preview in these experiments differed from the observations made in our second experiment in which we obtained equivalent mean boundary ratings regardless of whether the observers had knowledge of the larger spatial context in which the perceived scene took place or not. Although the comparisons made with Munger et al.’s (2005) or DeLucia and Maldia’s (2006) studies seem interesting, since they are—to our knowledge—the only studies in which a preview has been provided, these comparisons must be considered carefully, due to a number of methodological differences. Indeed, in these authors’ studies, the preview was included in the approach sequence, and the durations of the preview and of the tested close-up view were the same (Munger et al., 2005). In the present study, however, the preview scenes were presented as a separate event and were of longer duration. Another point to note is on the spatial scale of the stimuli, in which the difference between the stimulus view and the preview was much greater in the present study than in those of Munger et al. and DeLucia and Maldia. For these reasons, the differences between wide-angle and close-up views may have been less salient in these authors’ studies, and therefore more confusable.

A last point that needs to be discussed is the difference in the findings as a function of exposure duration. As a reminder, in the case of long exposures, no directional memory distortion or, at least, a reduction in BE was observed in the preexposure condition, whereas we observed equivalent BE in both the preexposure and control conditions with brief exposure duration. Time to mentally compare the preexposure and the stimulus views may account for this difference. In the long-term version, the memory test is a traditional situation of comparison between two external sources of information (i.e., information acquired during preview and memorization). By comparison, in the short-term version of the memory test, the external–external comparison would not have time to occur. Because of the brief delay between picture presentation and memory test, it seems plausible that the observers would not have enough time to identify the picture, retrieve the memory of the very wide-angle picture, and make a comparison. Thus, in this condition, they would be immediately affected by the reality monitoring error classically observed in BE. Moreover, considering the spatial rescaling hypothesis described earlier, with brief exposure times, the observers may not have had time to engage in the rescaling process, at least not consciously or intentionally, leaving BE unaffected by the preview.

Such observations raise the questions of memory registers involved in these effects and of the nature of the retrieval

processes. Thus, one hypothesis is that pictures of the preexposure phase would be retrieved from long-term declarative memory, involving explicit retrieval processes, whereas the extrapolation processes classically associated with BE (i.e., as in the control conditions of our experiments) would refer to perceptual extrapolations from implicit memory. In the same way, one question that arises is whether BE is a phenomenon that supposedly relies primarily on generic knowledge (i.e., abstract knowledge), relative to the semantic category of the perceived scene, rather than on specific knowledge, relative here to the very wide-angle version of the scenes perceived during the preexposure phase. In most situations, observers have a general knowledge about scenes and objects: For instance, in the “classical” picture from Intraub et al. (1996), which featured a bear on a staircase, observers had a general knowledge of what a staircase is. However, the observer might also have specific knowledge relative to the perceived scene: He/she might know this specific staircase or what really lies outside the picture. As was previously suggested, the need for prediction would be less important when the observer has specific knowledge relative to the larger spatial context in which the perceived scene takes place, causing fewer directional memory errors.

In conclusion, current theories have emphasized the facilitating effect of context on visual scene perception (e.g., Bar, 2004). The present study demonstrated that the effect of a preview on spatial layout extrapolation manifests itself under different forms as a function of scene exposure duration. Indeed, no effect of preview was observed with short exposures (i.e., with presentation times commensurate with eye fixation); this is consistent with the idea that BE could contribute to the perception of a stable and continuous visual world (e.g., Dickinson & Intraub, 2008; Intraub & Dickinson, 2008; Intraub et al., 1996). However, the effect of contextual knowledge was manifested as a reduction (or even absence under some conditions) of BE with longer exposures (i.e., with presentation durations allowing in-depth processing of visual information). These findings seem to be coherent at the functional level, in the sense that the need for prediction would be greater when the observer has no knowledge of the environment in which he/she is embedded, his/her ultimate goal being to produce appropriate interactions with situations encountered. Conversely, the visual system would engage in fewer predictions when the observer is aware of the larger spatial context in which a scene takes place. As Bar (2007, p. 287) wrote, “Humans seem to minimize processing of incoming information when this information is predictable (e.g., habituation, repetition blindness, change blindness, inhibition of return), and in parallel encourage the allocation of mental resources to unexpected and/or novel information (e.g., orienting response toward novel and unexpected stimuli, perceptual pop-out).” This suggests that the reduction of BE observed in our research may be adaptive and might be

interpreted as a facilitating effect of context that enables an observer to orient his/her attention to other more relevant dimensions of the environment once spatial layout is established.

Author note The authors warmly thank Evelyne Marmèche and three anonymous reviewers whose comments and suggestions helped them to improve this work. The English of this manuscript has been revised with funding from the University of Angers and of the Laboratoire de Psychologie des Pays de la Loire (UPRES EA 4638, Angers, France). The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

- Bar, M. (2004). Visual objects in context. *Nature Reviews Neuroscience*, 5, 617–629. <https://doi.org/10.1038/nrn1476>
- Bar, M. (2007). The proactive brain: Using analogies and associations to generate predictions. *Trends in Cognitive Sciences*, 11, 280–289. <https://doi.org/10.1016/j.tics.2007.05.005>
- Bertamini, M., Jones, L. A., Spooner, A., & Hecht, H. (2005). Boundary extension: The role of magnification, object size, context, and binocular information. *Journal of Experimental Psychology: Human Perception and Performance*, 31, 1288–1307. <https://doi.org/10.1037/0096-1523.31.6.1288>
- Biederman, I. (1972). Perceiving real-world scenes. *Science*, 177, 77–80. <https://doi.org/10.1126/science.177.4043.77>
- Biederman, I., Mezzanotte, R. J., & Rabinowitz, J. C. (1982). Scene perception: Detecting and judging objects undergoing relational violations. *Cognitive Psychology*, 14, 143–177. [https://doi.org/10.1016/0010-0285\(82\)90007-X](https://doi.org/10.1016/0010-0285(82)90007-X)
- Biederman, I., Rabinowitz, J. C., Glass, A. L., & Stacy, E. W. (1974). On the information extracted from a glance at a scene. *Journal of Experimental Psychology*, 103, 597–600. <https://doi.org/10.1037/h0037158>
- Blättler, C., Ferrari, V., Didierjean, A., Van Elslande, P., & Marmèche, E. (2010). Can expertise modulate representational momentum? *Visual Cognition*, 18, 1253–1273.
- Chapman, P., Ropar, D., Mitchell, P., & Ackroyd, K. (2005). Understanding boundary extension: Normalisation and extension errors in picture memory among adults and boys with and without Asperger’s syndrome. *Visual Cognition*, 12, 1265–1290.
- Cohen, J., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: An interactive graphic system for designing and controlling experiments in the psychology laboratory using Macintosh computers. *Behavioral Research Methods, Instruments, & Computers*, 25, 257–271. <https://doi.org/10.3758/BF03204507>
- Czigler, I., Intraub, H., & Stefanics, G. (2013). Prediction beyond the borders: ERP indices of boundary extension-related error. *PLoS ONE*, 8, e74245. <https://doi.org/10.1371/journal.pone.0074245>
- Davenport, J. L., & Potter, M. C. (2004). Scene consistency in object and background perception. *Psychological Science*, 15, 559–564. <https://doi.org/10.1111/j.0956-7976.2004.00719.x>
- DeLucia, P. R., & Maldia, M. M. (2006). Visual memory for moving scenes. *Quarterly Journal of Experimental Psychology*, 59, 340–360. <https://doi.org/10.1080/17470210500151444>
- Dickinson, C. A., & Intraub, H. (2008). Transsaccadic representation of layout: What is the time course of boundary extension? *Journal of*

- Experimental Psychology: Human Perception and Performance*, 34, 543–555.
- Didierjean, A., Ferrari, V., & Blättler, C. (2014). Role of knowledge in motion extrapolation: The relevance of an approach contrasting experts and novices. In B. H. Ross (Ed.), *The psychology of learning and motivation* (Vol. 61, pp. 215–235). Burlington, VT: Academic Press.
- Freyd, J. J., & Finke, R. A. (1984). Representational momentum. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 10, 126–132. <https://doi.org/10.1037/0278-7393.10.1.126>
- Gagnier, K. M. (2010). Rethinking boundary extension: The role of source monitoring in scene memory. Retrieved from ProQuest Dissertations and Theses (Accession Order No. [854499379]).
- Gagnier, K. M., Dickinson, C. A., & Intraub, H. (2013). Fixating picture boundaries does not eliminate boundary extension: Implications for scene representation. *Quarterly Journal of Experimental Psychology*, 66, 2161–2186.
- Gagnier, K. M., & Intraub, H. (2012). When less is more: Line-drawings lead to greater boundary extension than color photographs. *Visual Cognition*, 20, 815–824.
- Gottesman, C., & Intraub, H. (2003). Constraints on spatial extrapolation in the mental representation of scenes: View-boundaries versus object-boundaries. *Visual Cognition*, 10, 875–893. <https://doi.org/10.1080/13506280344000130>
- Gottesman, C. V. (2011). Mental layout extrapolations prime spatial processing of scenes. *Journal of Experimental Psychology: Human Perception Performance*, 37, 382–395.
- Gottesman, C. V., & Intraub, H. (2002). Surface construal and the mental representation of scenes. *Journal of Experimental Psychology: Human Perception and Performance*, 28, 589–599.
- Hubbard, T. L. (2005). Representational momentum and related displacements in spatial memory: A review of the findings. *Psychonomic Bulletin & Review*, 12, 822–851. <https://doi.org/10.3758/BF03196775>
- Hubbard, T. L. (2015). The varieties of momentum-like experience. *Psychological Bulletin*, 141, 1081–1119. <https://doi.org/10.1037/bul0000016>
- Hubbard, T. L., & Bharucha, J. J. (1988). Judged displacement in apparent vertical and horizontal motion. *Perception & Psychophysics*, 44, 211–221. <https://doi.org/10.3758/BF03206290>
- Intraub, H. (2004). Anticipatory spatial representation of 3-D regions explored by sighted observers and a deaf-and-blind observer. *Cognition*, 94, 19–37.
- Intraub, H. (2010). Rethinking scene perception: A multisource model. In B. H. Ross (Ed.), *The psychology of learning and motivation* (Vol. 52, pp. 231–264). Burlington, VT: Academic Press.
- Intraub, H. (2012). Rethinking visual scene perception. *Wiley Interdisciplinary Reviews: Cognitive Science*, 3, 117–127.
- Intraub, H., Bender, R. S., & Mangels, J. A. (1992). Looking at pictures but remembering scenes. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 18, 180–191. <https://doi.org/10.1037/0278-7393.18.1.180>
- Intraub, H., & Berkowitz, D. (1996). Beyond the edges of a picture. *American Journal of Psychology*, 109, 581–598.
- Intraub, H., & Bodamer, J. L. (1993). Boundary extension: Fundamental aspect of pictorial representation or encoding artifact? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 19, 1387–1397. <https://doi.org/10.1037/0278-7393.19.6.1387>
- Intraub, H., Daniels, K. K., Horowitz, T. S., & Wolfe, J. M. (2008). Looking at scenes whereas searching for numbers: Dividing attention multiplies space. *Perception & Psychophysics*, 70, 1337–1349.
- Intraub, H., & Dickinson, C. A. (2008). False memory 1/20th of a second later: What the early onset of boundary extension reveals about perception. *Psychological Science*, 19, 1007–1014.
- Intraub, H., Gottesman, C. V., Willey, E. V., & Zuk, I. J. (1996). Boundary extension for briefly glimpsed photographs: Do common perceptual processes result in unexpected memory distortions? *Journal of Memory and Language*, 35, 118–134.
- Intraub, H., Hoffman, J. E., Wetherhold, C. J., & Stoehs, S.-A. (2006). More than meets the eye: The effect of planned fixations on scene representation. *Perception & Psychophysics*, 68, 759–769. <https://doi.org/10.3758/BF03193699>
- Intraub, H., Morelli, F., & Gagnier, K. M. (2015). Visual, haptic and bimodal scene perception: Evidence for a unitary representation. *Cognition*, 138, 132–147.
- Intraub, H., & Richardson, M. (1989). Wide-angle memories of close-up scenes. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 15, 179–187. <https://doi.org/10.1037/0278-7393.15.2.179>
- Johnson, M. K., Hashtroudi, S., & Lindsay, D. S. (1993). Source monitoring. *Psychological Bulletin*, 114, 3–28. <https://doi.org/10.1037/0033-2909.114.1.3>
- Mamus, E., & Boduroglu, A. (2018). The role of context on boundary extension. *Visual Cognition*, 26, 115–130. <https://doi.org/10.1080/13506285.2017.1399947>
- Ménétrier, E., Didierjean, A., & Robin, F. (2017). Effect of expertise on boundary extension in approach sequences. *i-Perception*, 8(5). <https://doi.org/10.1177/2041669517723652>
- Munger, M. P., & Multhaup, K. S. (2016). No imagination effect on boundary extension. *Memory & Cognition*, 44, 73–88.
- Munger, M. P., Owens, R. T., & Conway, J. E. (2005). Are boundary extension and representational momentum related? *Visual Cognition*, 12, 1041–1056.
- Park, S., Intraub, H., Yi, D.-J., Widders, D., & Chun, M. M. (2007). Beyond the edges of a view: Boundary extension in human scene-selective visual cortex. *Neuron*, 54, 335–342.
- Potter, M. C. (1976). Short-term conceptual memory for pictures. *Journal of Experimental Psychology: Human Learning and Memory*, 2, 509–522. <https://doi.org/10.1037/0278-7393.2.5.509>
- Quinn, P. C., & Intraub, H. (2007). Perceiving “outside the box” occurs early in development: Evidence for boundary extension in 3- to 7-month old infants. *Child Development*, 78, 324–334.
- Roediger, H. L., III. (1996). Memory illusions. *Journal of Memory and Language*, 35, 76–100. <https://doi.org/10.1006/jmla.1996.0005>
- Seamon, J. G., Schleger, S. E., Heister, P. M., Landau, S. M., & Blumenthal, B. F. (2002). Misremembering pictured objects: People of all ages demonstrate the boundary extension illusion. *American Journal of Psychology*, 115, 161–167.
- Thornton, I. M., & Hayes, A. E. (2004). Anticipating action in complex scenes. *Visual Cognition*, 11, 341–370.