Visual Search and Concealment Strategies in the Spatiotemporal and the Temporal Domains across Social Contexts

by

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ABSTRACT

Although visual search studies have primarily focused on search behavior, concealment behavior is also important in the real world. However, studies of this topic are limited in that their findings about search and concealment strategies are restricted to the spatial domain, and do not include the temporal domain. This dissertation examined search and concealment strategies in the spatiotemporal and the purely temporal domains by modifying the hide-find paradigm of Anderson et al. (2014) and Street et al. (2018) in the spatial domain. Specifically, I set up situations in which the items were stacked sequentially in Chapter 2 (Experiments 1–4) and appeared in sequential order while eliminating the spatial factors associated with the items in Chapter 3 (Experiments 5–7).

The set of four experiments reported in Chapter 2 evaluated strategies during spatiotemporal search and concealment to determine whether observers would indicate where they would hide or find a target in a temporal sequence of items. The items were stacked in an upward (Experiments 1–3) or a downward (Experiment 4) direction to contain the spatial components in the sequentially presented items. The task scenario (hide or seek), social context (e.g., partner type: friend or foe), and oddball (unique item in the sequence: present or absent) were manipulated as key factors that could contribute to target selection. Analyses showed that observers in both the hide and seek scenarios frequently selected the oddball for friends, but not foes, which suggests that

they applied common strategies because the oddball automatically attracts attention and can be readily discovered by friends. A principle unique to the spatiotemporal domain was also revealed, i.e., when an oddball was absent, participants in both scenarios frequently selected the topmost stacked item for friends, regardless of the temporal order, whereas they selected the first item in the sequence for foes, regardless of the stacking direction. These principles were not affected by visual masking or the number of sequence items. Overall, these results suggest that finding and hiding positions in the spatiotemporal domain rely on the presence of salient items and physical accessibility, or temporal remoteness, across partner type.

The set of three experiments reported in Chapter 3 examined search and concealment behaviors in the purely temporal domain and identified temporal principles of search and concealment by eliminating the spatial components related to the stacked items used in Chapter 2. The results revealed a principle unique to the temporal domain: observers selected a target position based on biases similar to the serial position effects (e.g., primacy and recency effects) in the friend context when they engaged in both task scenarios. By contrast, observers were more likely to select a position based on temporal remoteness, which posits that earlier items were non-salient in the foe context. The selection biases were consistent with the spatiotemporal search and concealment selections in Chapter 2. However, the selections based on temporal remoteness were not always effective, while a random selection that posits placing or picking up a target in completely random positions to optimize the probability of winning the game was observed in some cases. These results suggest that hiding and finding positions in the temporal domain were determined by biases based on serial position effects, temporal remoteness, or random selection, across partner type. Finally, when the temporal sequence contains an oddball, observers selected the oddball for/from a friend relatively more frequently, whereas in the foe context the observers avoided selecting it, suggesting that strategies based on the saliency of the oddball items were common in any temporal and spatial domain.

In conclusion, the aforementioned results demonstrate that search and concealment strategies differ dramatically depending on the social context (i.e., friend or foe) and the presence or absence of salient items in the spatiotemporal and the temporal domains. This contributes to understanding of the metacognitive estimation in the interpersonal situation and is an initial step toward identifying the essential mechanism of search and concealment underlying various aspects of daily life. Limitations of the present research and further directions are also discussed.

CHAPTER 1. INTRODUCTION

1.1. Visual Search[1]

Previous studies investigating visual search have primarily focused on search behaviors (Awh, Belopolsky, & Theeuwes, 2012; Carrasco, 2011), which seems reasonable because visual search is indispensable to everyday situations such as looking for a house key on a messy desk or identifying desired products in a supermarket. Reflecting these behaviors on cognitive researches, observers search for a visual target amidst a variable number of distractors during an ordinary spatial visual search task (Treisman & Gelade, 1980; Wolf, 2010; Wolfe & Horowitz, 2017). During this selection process, visual attention plays a critical role in a cluttered visual environment in achieving our current behavioral goals (Desimone & Duncan, 1995; Lamy, Leber, & Egeth, 2012; Theeuwes, 2010, 2014).

Researchers have reached a general consensus that allocation of attention is determined through an interplay among bottom-up (salience-driven), top-down (goal-driven), and selection history (value-driven) mechanism of attentional guidance (Anderson, 2013; Awh et al., 2012; Theeuwes, 2019). Bottom-up selection refers to automatic and compulsory attention to salient stimuli (Itti & Koch, 2000, 2001; Van der Stigchel et al., 2009). Top-down selection refers to flexibly programmable and adaptive guidance of attention toward an object with a particular property based on the observer's prior knowledge (a template or “attentional control setting”; Bacon & Egeth, 1994; Egeth, Leonard, & Leber, 2010). Selection history refers to lingering and enduring selection biases based on prior attentional deployments or reward learning regardless of the current goals or the stimulus-driven saliency of objects (Anderson, 2016; Mine & Saiki, 2015).

The flexibility of attentional selection has been demonstrated in the literature, indicating that observers can search for a target defined by various types of stimulus features, such as color (Folk, Remington, & Johnston, 1992; Nagy & Sanchez, 1990; Navalpakkam & Itti, 2006), intensity (Navalpakkam & Itti, 2006), motion (Dick, Ullman, & Sagi, 1987), shape (Treisman & Gormican, 1988), depth (He & Nakayama, 1992), and size (Hodsoll & Humphreys, 2001; Navalpakkam & Itti, 2006). Similarly, observers can search for targets adaptively even if the targets are defined by arbitrary combinations of these features (Adamo, Pun, & Ferber, 2010; Adamo, Pun, Pratt, & Ferber, 2008; Adamo, Wozny, Pratt, & Ferber, 2010; Irons & Remington, 2013; Ito & Kawahara, 2016; Moore & Weissman, 2010, 2011, 2014; Parrott, Levinthal, & Franconeri, 2010; Roper & Vecera, 2012; Shen, Reingold, & Pomplun, 2000).

Visual attention can also be allocated in time as well as space (Coull, Frith, Büchel, & Nobre, 2000; Coull & Nobre, 1998; Martens & Johnson, 2005; Mento & Tarantino, 2015; Nobre & Van Ede, 2018). A popular paradigm known as rapid serial visual presentation (Martens & Wyble, 2010; McLean, Broadbent, & Broadbent, 1983;

Shapiro, Arnell, & Raymond, 1997) that a stream of a target (e.g., letter) and non-targets or distractors (e.g., numerical character) is sequentially presented in a same spatial location at rate of about 10 items per a second, is often used to manipulate the factors involved in the allocation of attention in the temporal domain (e.g., Chun & Potter, 1995; Ito & Kawahara, 2016; Martens & Wyble, 2010; Raymond, Shapiro, & Arnell, 1992). To achieve current goals of individuals, it is necessary to select task-relevant objects as well as spatial, temporal, or spatiotemporal locations while restricting the processing of irrelevant information because the visual system is limited in terms of its capacity to recognize many stimuli at once (Lamy et al., 2012; Rohenkohl, Coull, & Nobre, 2011; Wolfe & Horowitz, 2017).

Research on visual attention has examined a wide range of factors that improve or impair visual search performance by manipulating the visual properties of targets and controlling the allocation of spatial, temporal, or spatiotemporal attention (Pastukhov, Vonau, Stonkute, & Braun, 2013; Smilek, Weinheimer, Kwan, Reynolds, & Kingstone, 2009; Wolfe & Horowitz, 2017). For example, the saliency of a target can influence search performance. Generally, a search is more efficient when target saliency is high compared to when the saliencies of the target and non-targets are similar (Becker, 2010; Duncan & Humphreys, 1989; Liesefeld, Moran, Usher, Müller, & Zehetleitner, 2016; Pashler, 1987; Smilek et al., 2009). Moreover, there are many other factors known to influence such search difficulty on visual spatial searches: set size in a search display (Treisman & Gelade, 1980), presence of a task-irrelevant distractor (Forster & Lavie, 2008; Ito & Kawahara, 2017), target eccentricity (Scialfa & Joffe, 1998), presence or absence of a target (Chun & Wolfe, 1996), distractor heterogeneity (Duncan & Humphreys, 1989), search asymmetry (Treisman & Souther, 1985; Wolf, 2001), emotional valance (Frischen, Eastwood, & Smilek, 2008), categorical membership (Daoutis, Pilling, & Davies, 2006), crowding (Vlaskamp & Hooge, 2006), target prevalence (Wolfe, Horowitz, & Kenner, 2005), spatial context and layout (Chun & Jiang, 1998; Ono, Jiang, & Kawahara, 2005). Furthermore, due to low levels of resource allocation, target identifications are impaired during a visual search in the temporal domain when the target is embedded within a rapid sequence of non-target letters that appear relatively early in the sequence (Ambinder & Lleras, 2009; Ariga, Kawahara, & Watanabe, 2011; Ariga & Yokosawa, 2008; Kranczioch & Bryant, 2011; Kranczioch & Dhinakaran, 2013). There are also other factors known to influence the search difficulty in the temporal domain: presentation rates (Potter & Faulconer, 1975; Potter, Wyble, Hagmann, & McCourt, 2014), temporal context such as prioritizing an upcoming target at specific points in time (Olson & Chun, 2001; Nobre & Van Ede, 2018), number of targets (e.g., attentional blink; Di Lollo, Kawahara, Ghorashi, & Enns, 2005; Raymond et al., 1992), vigilance (Griffin, Miniussi, & Nobre, 2001).

The abovementioned visual search studies in humans revealed the role of visual attention by focusing on the search for particular items in one's field of view or in the temporal sequence. However, visual concealment may also be important to one's daily life, and in various contexts. For example, it is sometimes necessary for people to hide or protect an important object from other people (e.g., thieves). Conversely, people sometimes need to display an object so that others (e.g., customers) can readily find them. Thus, it is important to know when it is reasonable to hide or display a target in various situations. Surprisingly, few studies have addressed this issue despite the relatively close relationship between visual search and visual concealment (Smilek et al., 2009) and, thus, the present study evaluated the search and concealment strategies used by human adults in the temporal domain. However, because concealment behaviors are not limited to human adults and are also observed in different populations and species, this article will provide a brief overview of the search and concealment strategies of children and animals.

1.2. Visual Search and Concealment Strategies in Children and Animals

Of the relatively few studies that have assessed the visual search and/or concealment strategies of children, most have investigated the effects of developmental stage or memory function. Wellman, Somerville, and Haake (1979) evaluated the development of search procedures by children in a real-life environment using 2- to 6-year-olds who were instructed to search for a target among eight widely distributed locations in a school playground or room. During the task, older children were more likely than younger children to search systematically for a target (e.g., checking each location sequentially from the nearest starting position), which indicates that developmental stage is critical for efficient or comprehensive searches. Cornell and Heth (1986) investigated hiding and searching strategies in 6- to 8-year-old children who were asked to complete a “treasure hunt” task. In this task, the children hid 20 items at 100 possible locations around a room and were then asked to recover the items after a delay. Although children were likely to cluster their selections when hiding, older children were more likely than younger children to hide the items in widely distributed positions across the clusters. The authors suggested that older children can scatter items because their memory capacity is larger than that of younger children. Additionally, the authors reported that when children recover items, young children are more likely than older children to find items using a simpler search path. Several other studies have also revealed that comprehensive search and concealment strategies are observed in children as they become older (Cornell & Heth, 1983; Nichols-Whitehead & Plumert, 2001; Wellman, Somerville, Revelle, Haake, & Sophian, 1984).

In animal studies, investigating memory function in terms of food caching and recovery can provide an indication of search and concealment behaviors. It is well known that food-caching animals, such as birds and mammals, hide food for future consumption and recover the cached food based on memory (Brodin, 2010). Additionally, food-caching behavior is sometimes performed in the long-term, such as during winter, which means that food-caching animals need to hide or protect food from other individuals as well as remember the precise spatial locations of the caches so that other individuals cannot find the food (Andersson & Krebs, 1978). For example, Clark's nutcrackers, marsh tits, and scrub jays can remember the spatial location of a cache for 2 weeks to 9 months (Balda & Kamil, 1992; Healy & Suhonen, 1996) and also remember the contents of their caches (Clayton & Dickinson, 1999). Compared to humans, the precision of these memories is incredibly high. For example, Western scrub jays can remember the various spatial locations of their caches as well as when the food was cached, taking into account the maturation and perishability of the food (Clayton & Dickinson, 1998). Thus, these birds can remember the spatial locations of food as well as temporal information about each cached food item. The capabilities of birds in terms of their food-caching behaviors are reflected in the volume of the hippocampal complex, which is larger in food-caching species than in species that do not cache food (Krebs, Sherry, Healy, Perry, & Vaccarino, 1989; Sherry, 2011).

Similar to humans, animals also systematically and comprehensively hide or search for foods. For example, scatter hoarding is observed in various species of birds and mammals (Brodin, 2010) and rodents are known to store their food in distributed locations (Vander Wall, 1990). Furthermore, Western scrub jays hide food in shaded or occluded locations (Dally, Emery, & Clayton, 2004, 2005) and caching birds are more likely to choose hiding locations farther away from observers when they are present

(Emery & Clayton, 2001). The abovementioned behaviors are also observed in humans (Cornell & Heth, 1986; Legge et al., 2012; Talbot, Legge, Bulitko, & Spetch, 2009). Moreover, dogs can detect hidden food based on human communicative cues, such as pointing gestures, and apes can detect food based on causality, such as physical laws (Bräuer, Kaminski, Riedel, Call, & Tomasello, 2006; Call, 2004).

The relevant literature is exemplified by the abovementioned studies, which have revealed search and concealment strategies in children and animals by focusing on developmental stage, memory, executive function, and intelligence. However, the developmental stage and abilities of human adults are virtually identical and, thus, search and concealment strategies in adults are likely to involve cognitive biases (e.g., attendance to a salient object or a particular position in space or time) or knowledge about search difficulties based on personal experience (e.g., Smilek et al., 2009). Thus, the following section of this article will review the search and the concealment strategies of human adults in more detail below while highlighting their uses in a social context, unique to humans.

1.3. Visual Search and Concealment Strategies in Human Adults and Social Context

Several recent studies have investigated concealment behavior by human adults in addition to search behavior (Anderson, Foulsham, Nasiopoulos, Chapman & Kingstone, 2014; Legge et al., 2012; Smilek et al., 2009; Street, Bischof, & Kingstone, 2018; Talbot et al., 2009). In a real-world situation, people sometimes display or hide an object (e.g., a Christmas present or recommended products) so that others (e.g., family members or customers) will find it whereas others (e.g., thieves) will not be able to find it (e.g., a house key or a bankbook). In fact, there is a close relationship between visual search and concealment (e.g., Smilek et al., 2009; Talbot et al., 2009). For example, concealed positions are applied to the basic strategies of visual search, i.e., observers can appropriately hide a visual target from others based on their knowledge of the visual search difficulties that will be encountered by finders (Legge et al., 2012; Smilek et al., 2009). Therefore, further elucidating visual concealment behavior will be important for understanding the human cognitive processes involved in visual search. Typically, visual search and concealment studies are divided into experiments using a classical simple array, such as a homogenous or pop-out display (Anderson et al., 2014; Street et al., 2018), or by using complex visual scenes or stimuli, such as a room or emotional faces (Legge et al., 2012; Smilek et al., 2009; Talbot et al., 2009). The present study explored strategies for hiding and finding using the former standard experimental situation.

Comprehensive search and concealment behaviors are observed in human adults in both real and virtual environments (Legge et al., 2012; Talbot et al., 2009). For example, Talbot et al. (2009) examined search and hiding behaviors in adults using the treasure hunt task that was employed by Cornell and Heth (1986) to examine these behaviors in children. Talbot et al. (2009) had the adult participants search for or hide three items in nine possible spatial locations and revealed several important principles about search and concealment. Similar to the comprehensive search and concealment behaviors of children and animals (e.g., Cornell & Heth, 1986; Emery & Clayton, 2001), the selections by adults were also non-random during both the searching and hiding tasks. This finding indicates that the participants applied specific strategies, such as moving farther away from the starting point and dispersing their choices to a greater degree when hiding items compared to when they were searching for items. Likewise, Legge et al. (2012) reported that, rather than making random selections, participants select locations further from the origin and choose more dispersed locations when hiding, as compared to when searching.

To investigate search and concealment strategies in the spatial domain as a fundamental attempt, Anderson et al. (2014) and Street et al. (2018) developed a novel task, the hide-find paradigm, which is a kind of treasure-hunting task that introduces partner type (e.g., friend or foe) as a dependent variable. In this task, participants in the friend context (or foe, who was a fictional opponent) were either instructed to indicate where they would hide a critical item (e.g., a house key) in spatially distributed visual arrays (4 × 4 grid of boxes) or asked to find a target that had been hidden by a friend or a foe in a block-wise manner. In other words, if the partner was a friend, then participants in the hide scenario chose a target position so that friends would find the target whereas participants in the seek scenario chose a target position that had been hidden by friends so that the participants would find it. In contrast, if the partner was a foe, the participants in the hide scenario chose a target position so that the foe would not find the target, whereas participants in the seek scenario chose a target position that had been hidden by the foe so that the participants would not find it. Additionally, under these tasks, the visual arrays were manipulated to produce two conditions: homogenous displays, which consisted of visual arrays of uniform boxes (i.e., oddball-absent condition), and pop-out displays, which consisted of visual arrays with a unique box (i.e., oddball-present condition). Then, the frequencies of each spatial location selected as a target position by the participants were recorded.

Through this hide-find paradigm, spatial principles based on partner type (friend or foe) are observed when participants engage in spatial hide and seek tasks (Anderson et al., 2014; Street et al., 2018). For instance, under the oddball-present condition, participants in both the hide and seek scenarios are more likely to select the oddball when the partner is a friend whereas they avoid selecting the oddball when the partner is a foe. These results indicate that participants execute strategies assuming that the oddball would capture the attention of friends (or foes) and, thus, be easily discovered by friends (or foes). Importantly, under the oddball-absent condition, participants in both the hide and seek scenarios were likely to select the items at spatially corner positions of visual arrays when the partner was a friend whereas they were more likely to select items at centrally converged positions when the partner was a foe. Anderson et al. (2014) suggested that the former result is consistent with natural intuitions during search and concealment (Smilek et al., 2009) such that placing a critical target at edge positions leads to easier search because placing objects at the edges provides a salient feature that supports pop-out detection. Additionally, these authors suggested that the latter result reflects the notion that a critical target is well-camouflaged when surrounded by various items. Taken together, from the perspective of the fundamental principles of hiding and finding, these results suggest that human adults are more likely to hide and search for an item that would attract attention physically and spatially for/from friends whereas they would hide and search for an item that is not salient for/from foes. However, the current explanations of the principles underlying search and concealment remain insufficient because previous studies have primarily focused on spatial factors and left temporal factors relatively unexplored (e.g., the presentation order of items).

1.4. Purpose of the Present Study

This dissertation examined search and concealment strategies in the temporal and spatiotemporal domains by introducing the hide-find paradigm of Anderson et al. (2014) and Street et al. (2018) in the spatial domain to set up situations in which the items were stacked in Chapter 2 (Experiments 1–4) and/or appeared in sequential order in Chapter 3 (Experiments 5–7). Following reported procedures, this study manipulated the task scenario (hide or seek), partner type (e.g., social context: friend or foe), and oddball (presence or absence of a unique item in the sequence) as key factors that could contribute to the selection of a target position. Then, it examined several hypotheses about the strategies in each Chapter. For example, if biases similar to serial presentation effects (recency and primacy effects; Grenfell-Essam & Ward, 2012; Murdock Jr, 1962) were reflected in the target selections, the first and last items would be more likely to be selected in a friend context. If the spatial principles of search and concealment were applied to cases when an oddball was present, observers should select the oddball in a friend context, whereas they would avoid selecting the oddball in a foe context.

The final goal of this study was to determine patterns of target selection in each situation and identify what metacognitive estimation observers would use to select targets. In Chapter 4, as a unique aspect of this study, hit rates between the selection of finders and hiders were simulated, although the participants had only guessed a target position, without feedback regarding the success (or failure) of the search and concealment in the previous hide-find paradigm. It is possible to estimate how accurately observers can access others' intentions. Finally, I discuss the potential mechanism of search and concealment in the spatiotemporal and temporal domains.

CHAPTER 2. SEARCH AND CONCEALMENT STRATEGIES IN THE SPATIOTEMPORAL DOMAIN

2.1. Overview

The present study investigated hiding and finding in a spatiotemporal domain and aimed to determine whether observers would indicate where they would find or hide a critical item in a temporal sequence. More specifically, the hide-find paradigm that has, to date, been exclusively used for hiding and finding in the spatial domain (Anderson et al., 2014; Street et al., 2018) was modified to assesses these circumstances in the spatiotemporal domain when items appeared sequentially in order and were stacked. Additionally, the present paradigm manipulated partner type (i.e., the interpersonal relationship between observers and fictional opponents: friend or foe) and the presence or absence of a unique item in the sequence (oddball). Because the fundamental principles of hiding and finding in the spatial domain can be applied to those in the temporal domain, it can be expected that participants will hide and find an item that would attract attention for/from friends whereas they will hide and search for the item that is not salient for/from foes. Therefore, it was predicted in the present study that the participants would be more likely to select the oddball (when present) for friends than for foes.

Importantly, the present study also focused on situations in which participants indicated where they would hide or find a target within a temporal sequence of items when the oddball was absent (i.e., homogenous display). If the spatial principles associated with hiding and seeking also apply to search and concealment in the spatiotemporal domain, then the participants would consider the first and last items to be more salient than other items because the first and last items in a temporal sequence are homologous to items located at the edge positions in a spatial array. Similarly, the items that were not first or last in a temporal sequence should be equivalent to those placed centrally or those that are camouflaged in a spatial array. Moreover, the first and last items should be more salient than the other items due to serial position effects, i.e., the primacy and recency effects (Grenfell-Essam & Ward, 2012; Murdock Jr, 1962). Therefore, it was expected in the present study that the first and last items would be more likely to be selected for a friend rather than a foe. The present study also examined the effects of visual masking (Experiment 2) and the specific number of items in a sequence (Experiment 3) on selections during hiding and finding to distinguish whether the selections were made due to perceptual visibility or temporal factors. Experiment 4 also examined the effect of stack direction of sequential items on the selections involved spatial factors.

2.2. Experiment 1

Experiment 1 was conducted to determine where participants would hide or find a target within a sequence of items that was stacked in an upward direction and whether the hiding/finding locations would vary depending on partner type (friend or foe) and the presence or absence of an oddball. Specifically, the participants viewed a temporal sequence of four items as if a suit of flipped playing cards was displayed sequentially. Then, each participant hid or searched for a critical target so that a fictional partner would (or would not) find the target or the target was hidden by a partner so that the participant would (or would not) find it. It was predicted that the participants would hide and find the target that attracted attention physically and spatially and/or temporally for/from friends whereas they would hide and search for a target that was not salient for/from foes. In other words, the participants would select the oddball for friends but select the non-oddball for foes. Furthermore, it was predicted that if the spatial principles and serial position effects apply to search and concealment in the spatiotemporal domain, then the first and last (fourth) items would be selected for friends whereas the other items would be selected for foes under the oddball-absent condition.

Method

Participants. The present study recruited 40 undergraduate and graduate students (19 females, between 18 and 32 years of age) from the participant pool at Hokkaido University, who participated in exchange for pay or course credit. Half of the participants (seven females, mean age = 19.65 years) were randomly assigned to the hide scenario while the other half (12 females, mean age = 21.05 years) were assigned to the seek scenario; this sample size was chosen based on those used in previous studies (Anderson et al., 2014; Street et al., 2018). All participants in this and the subsequent experiments reported normal or corrected-to-normal visual acuity and provided written informed consent according to approval by the Center for Experimental Research in Social Sciences of Hokkaido University.

Apparatus and Stimuli. All stimuli were presented on a 24-inch LCD monitor (100 Hz refresh rate, 1,920 × 1,080 pixels) controlled by a PC/AT-compatible computer operating with Linux, Matlab, and Psychophysics Toolbox (Brainard, 1997; Kleiner, Brainard, & Pelli, 2007; Pelli, 1997). The viewing distance was approximately 57 cm, all stimuli were displayed on a black background, and all responses were collected via a keyboard connected to the computer.

Participants viewed a sequence of four white cards with green polygon patterns that looked like the backs of playing cards (Figure 1). Each item subtended 22.3° in height and up to 15.0° in width. Most items flew from the bottom right of the screen to the center of the screen whereas the oddballs flew from the bottom left to the center. The items were stacked in an upward direction so that newly appeared items were placed over the old items. Each sequence lasted 3,000 ms (750 ms per card).

Design. The present experiment employed a 2 × 2 × 2 factorial design with one between-subjects factor, task scenario (hide or seek), and two within-subject factors, partner type (social context: friend or foe) and oddball (present or absent). In total, the experimental session consisted of 12 blocks and 144 trials. Half of the blocks were assigned to the friend context and the other half of the blocks were assigned to the foe context. The order alternated between the friend and foe contexts, and the initial condition (friend or foe) was counterbalanced within each task scenario group. Each block consisted of 12 trials and included four trials under the oddball-absent condition and eight trials under the oddball-present condition. The oddball was presented twice in each of the four possible temporal locations of the sequence and the order of trials was randomly determined within each block.

Procedure. The participants were asked to indicate where they would hide or find (i.e., task scenario) an item embedded within a temporal sequence of cards when dealing with a friend or foe (i.e., partner type) (see instructions in Table 1). In the hide scenario, participants were asked to select a temporal position to conceal an item so that a friend could choose or so that a foe could not choose it. In the seek scenario, participants were asked to select a temporal position of an item hidden by a friend so that the participant would find it or the position of an item that a foe had hidden, so that they would not find it.

Table 1

Different Instructions across the Task Scenario and Partner Type Conditions

Scenario	Partner Type	Instructions
Hide	Friend	*One of your cards is a winner, and the rest are losers. A fictional opponent draws a card, wanting to choose the winning card. You want to place this card in one of the four temporal positions so that your opponent will find it. Select the position where you would hide the card.*
Hide	Foe	*One of your cards is a winner, and the rest are losers. A fictional opponent draws a card, wanting to choose the winning card. You want to place this card in one of the four temporal positions so that your opponent will not find it. Select the position where you would hide the card.*
Seek	Friend	*One of cards held by your fictional opponent is a winner, and the rest are losers. You draw a card, wanting to choose the winning card. Your opponent wants to place the card in one of the four temporal positions so that you will find it. Select the position where you would find the card.*
Seek	Foe	*One of cards held by your fictional opponent is a winner, and the rest are losers. You draw a card, wanting to choose the winning card. Your opponent wants to place the card in one of the four temporal positions so that you will not find it. Select the position where you would find the card.*

Each trial began with written instructions (e.g., “Select the position where you would hide an object so that a foe could not find it” in Japanese) in the center of the screen and then participants initiated the trial by pressing the space bar. After a 500-ms interval with a blank screen, the temporal sequence started. All items of the sequence except for one slid from the bottom right of the screen to the center of the screen when no oddball was present. The unique item in the sequence (as an oddball), if any, slid into the display from the bottom left of the screen to the center of the screen; this exception occurred only in the oddball-present condition. The cards that slid into the display were stacked upward in the center of the display. After the presentation of the four items in the sequence, the participants guessed and reported the temporal position of the critical item by pressing a corresponding key on the numeric keypad (1, 2, 3, or 4) with no time constraints.

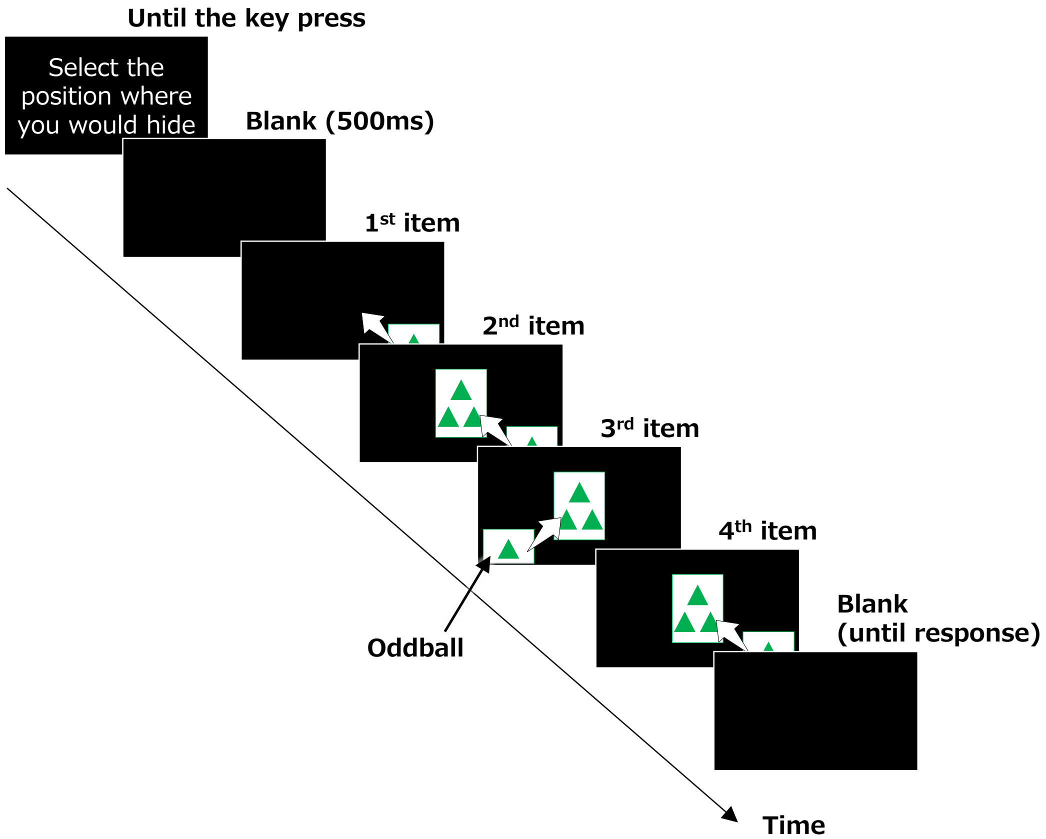

Figure 1. Semantic example of a single trial in the revised hide-find paradigm within the spatiotemporal domain (Experiment 1). All items in the sequence moved from the bottom right of the screen to the center of the screen when no oddball was present. When an oddball was present, one of the sequence items moved from the bottom left of the screen to the center of the screen while the remaining items moved from the bottom right to the center. Following the presentation of the sequence, participants guessed and reported the temporal location of the critical target across partner type (friend or foe) by pressing a corresponding key with no time constraints.

Results

Oddball-present condition. Figure 2 displays the mean frequencies of selecting the oddball item in each temporal position across scenario (hide or seek) and partner type (friend or foe). To assess whether the participants were biased toward oddball items, the frequencies of selecting the oddball for the task scenario and partner type conditions were compared using a two-way analysis of variance (ANOVA) with task scenario as a between-subjects factor and partner type as a within-subject factor. There was a main effect of task scenario (F (1, 38) = 4.33, p = .04, η_p^2 = .10), which indicates that the participants more frequently selected the oddball in the seek scenario than in the hide scenario. Additionally, the main effect of partner type was significant (F (1, 38) = 52.06, p < .001, η_p^2 = .58), which indicates that the participants more frequently selected the oddball for friends than for foes in both the hide and seek scenarios. The interaction between task scenario and partner type was not significant (F (1, 38) = 0.67, p = .42, η_p^2 = .02).

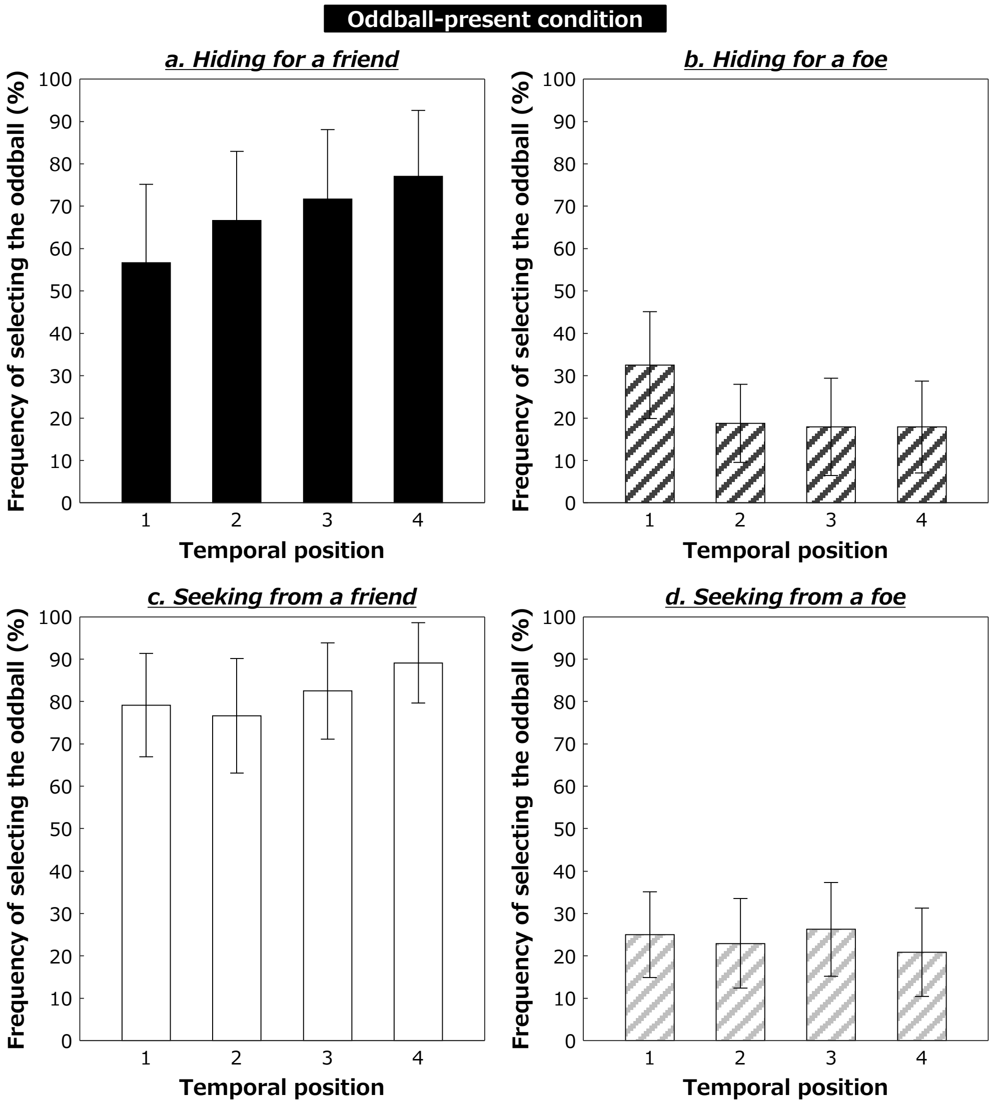

Figure 2. Mean frequencies of selecting the oddball in each temporal position across task scenario (hide or seek) and partner type (friend or foe) in Experiment 1. Error bars show 95% confidence intervals.

Oddball-absent condition. The frequencies of the item selections for each scenario and partner type were also compared when the oddball was absent. Chi-square analyses were conducted for each condition to examine whether the temporal positions of the selected items (e.g., first, second, third, and fourth items) were biased. Figure 3 displays the mean frequencies of selecting one of the four possible temporal positions for each partner type (friend or foe) and scenario (hide or seek). Chi-square tests revealed that the selections in the absence of the oddball were significantly biased by the temporal position when hiding for a friend (Figure 3a, top left; χ^2 (3, N = 480) = 95.03, p < .001, w = 0.45). Specifically, multiple comparisons assessed using binomial tests revealed that the fourth item was most frequently selected compared to the other temporal locations (ps < .001) and that the first item was least frequently selected relative to the other temporal locations (ps < .001) (the p-values included in all of the following analyses were adjusted based on the study performed by Benjamini & Hochberg, 1995). The selection frequencies between the second and third items did not differ (p = .31).

Similar Chi-square tests were applied to assess the probabilities of selections when hiding for a foe. These tests revealed a significant effect of temporal position (Figure 3b, top right; χ^2 (3, N = 480) = 185.88, p < .001, w = 0.62) such that the pattern of results contrasted sharply with the findings obtained when hiding for a friend. Specifically, the first item was most frequently selected (ps < .001) whereas the third item was least frequently selected relative to the other items (ps < .001). Additionally, the fourth item was selected more frequently than the second and third items (ps < .03).

Chi-square tests evaluating the seek scenario in the friend condition indicated that the selection was significantly biased (Figure 3c, bottom left; χ^2 (3, N = 480) = 330.32, $p < .001$, w = 0.83) such that the fourth item was most frequently selected (ps < .001) whereas the third item was least frequently selected (ps < .03). The selection frequencies between the first and second items did not differ ($p = .46$).

Finally, Chi-square tests applied to the seeking from a foe condition indicated a significant effect of temporal position (Figure 3d, bottom right; χ^2 (3, N = 480) = 70.15, $p < .001$, w = 0.38). Specifically, the first item was most frequently selected (ps < .001) whereas the fourth item was least frequently selected (ps < .03). The selection frequencies between the second and third items did not differ ($p = .78$).

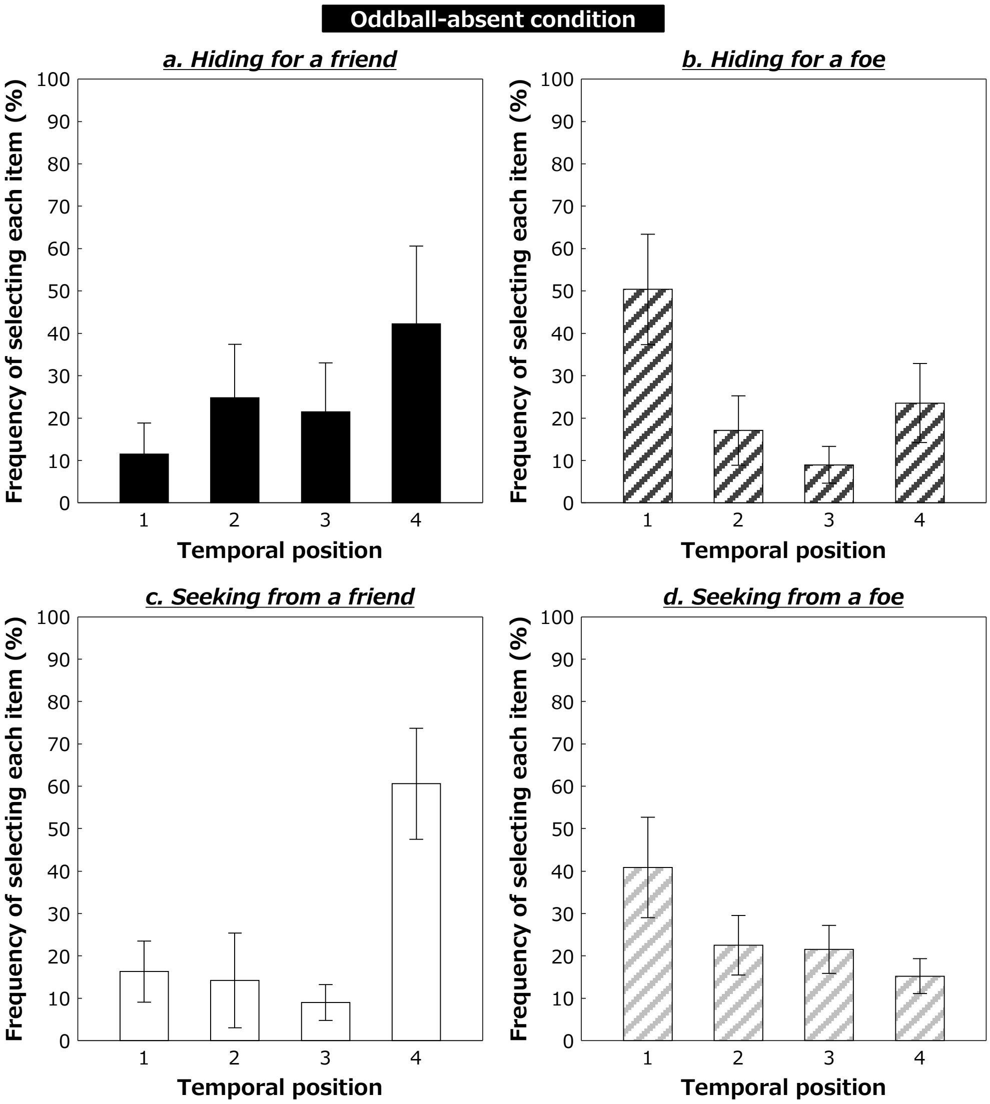

Figure 3. Frequencies of selecting the items in each temporal position under the oddball-absent condition across task scenario (hide or seek) and partner type (friend or foe) in Experiment 1. Error bars show 95% confidence intervals.

Discussion

As predicted, the participants more frequently selected the oddball for friends but more frequently avoided the oddball for foes, regardless of the hide or seek scenario. These strategies were identical to those used for search and concealment in the spatial domain (Anderson et al., 2014; Street et al., 2018). In other words, the participants applied the natural intuition (Smilek et al., 2009) that an oddball physically attracts attention and can be easy to discover for friends. This idea was originally observed in spatial search tasks (Anderson et al., 2014) and was shown to be applicable to the present temporal search task, even though the physical circumstances substantially differed. It is possible that the mere presence of an oddball and its conceptual similarity were sufficient for the participants to adopt the metacognition that a salient item in the present context would attract attention and, thus, be easily discovered by others in the temporal domain. Interestingly, participants in the seek condition selected the oddball more frequently than those in the hide condition (Figure 2a versus Figure 2c), which is consistent with previous findings (Anderson et al., 2014; Smilek et al., 2009) and suggests that hiding is a more complex process than finding.

The results in the oddball-absent condition were straightforward. Participants chose the fourth item most frequently and the first item least frequently for a friend relative to the other items, regardless of the hide or seek scenario. However, the pattern dramatically flipped for a foe such that participants chose the first item most frequently and the fourth item least frequently regardless of task scenario. These patterns of results cannot be explained by the primacy and recency effects of short-term memory because the biased choices of the first and fourth items were determined by the scenario (i.e., for a friend or foe). It is possible that the biased selections of sequentially presented items could be explained by the idea that the spatial structures of the items and their accessibility would be critical for selection. In fact, there is a close relationship between action and cognition (Hommel, 2015; Pratt & Abrams, 1994; Shin, Proctor, & Capaldi, 2010; Solman, Cheyne, & Smilek, 2012; Solman, Hickey, & Smilek, 2014; Street et al., 2018; Tipper, Lortie, & Baylis, 1992). For example, Street et al. (2018) found that, when participants selected items using a touch screen, they were more likely to select items based on a belief regarding the sitting position of a friend. More specifically, the participants selected closer items because they had shifted their own perspective to that of a friend, so that the target would be easy for the friend to reach. Similarly, the search was delayed and missed when participants unpacked heaps of items and searched for a particular target in such a 3-dimensional layout relative to when the participants searched for the target in a typical 2-dimensional layout of spatially distributed items (Solman et al., 2012; 2014). The items in Experiment 1 in the present study constituted a 3-dimensional structure and were stacked upward in order and, thus, the first item was the bottommost card and the fourth item was the topmost card in the stack. Therefore, this spatial structure would imply differential accessibilities of these items and could have resulted in the fourth and topmost item being most accessible whereas the first and bottommost item would be least accessible. These differences in accessibility rather than temporal factors (e.g., presentation order) could be reflected in the selections for friends versus those for foes in both the hide and seek scenarios.

Although this accessibility-based explanation appears reasonable, other possibilities should also be considered. For example, these differences could be related to perceptual visibility because no items followed the last item. Prior to examining the accessibility hypothesis, Experiment 2 was designed and conducted to dismiss the perceptual visibility hypothesis by introducing visual masking such that that the masking item appeared at the end of the temporal sequence.

2.3. Experiment 2

Experiment 2 included visual masking to determine whether the results of Experiment 1, showing the selection of the last (or topmost stacked) item for friends in the non-oddball condition, was due to the spatial structure of the visual array or to perceptual visibility. The procedures used in Experiment 1 were also used in this experiment except that visual backward masking was applied to the last item in the temporal sequence. If the perceptual visibilities of the first and last items were critical for the pattern of selections observed in Experiment 1, then there should be a lower (or higher) frequency of the selection of the last (or first) item in both the hiding and finding scenarios in Experiment 2, as compared to Experiment 1, when the participants acknowledged that a hider or finder was a friend (or foe). This is because, in Experiment 2, the visibility or saliency of the last item should decrease following the application of visual backward masking (e.g., the suffix effect; Hu, Hitch, Baddeley, Zhang & Allen, 2014; Morton, Crowder, & Prussin, 1971; Parmentier, Tremblay, & Jones, 2004). However, if physical accessibility was critical for the selections observed in Experiment 1, then comparable results would be obtained in Experiment 2 because the spatial structure of the visual array remained unchanged.

Additionally, the duration of time it took to make a selection in Experiment 2 was recorded using a method similar to that of Anderson et al. (2014), who reported a diverging of cognitive processes for search and concealment based on data regarding decision time. Specifically, participants took longer to make a selection when hiding an item from a foe than when searching for an item from a foe in the oddball-present condition. These results suggest that participants will apply more complex strategies when hiding than when searching under the foe context. Thus, the recording and analyzing of decision times will further the current understanding of the cognitive processes underlying search versus those underlying concealment.

Method

Participants. A new group of 40 undergraduate and graduate students (24 females; between 18 and 43 years of age) recruited from the participant pool at

Hokkaido University participated in exchange for pay or course credit. Half of the participants (14 females; mean age = 21.05 years) were randomly assigned to the hide scenario while the other half (10 females; mean age = 19.80 years) was assigned to the seek scenario.

Apparatus, Stimuli, Design, and Procedure. The apparatus, stimuli, and design of Experiment 2 were the same as those used in Experiment 1. However, Experiment 2 included a visual random-dot mask that was the same size as the items in the sequence and which appeared in the center of the screen for 100 ms after the presentation of the sequence with no inter-stimulus interval (Figure 4). The direction from which an oddball slid in was counterbalanced across trials. Specifically, the majority of items in the sequence slid into view equally often from the bottom right (or bottom left) of the screen to the center of the screen, while one of the four items slid in from the opposite side (as an oddball item), if at all. Additionally, in Experiment 2, the time it took from the offset of the visual mask to completion of the selection response was recorded even though the participants were not instructed to respond as quickly as possible.

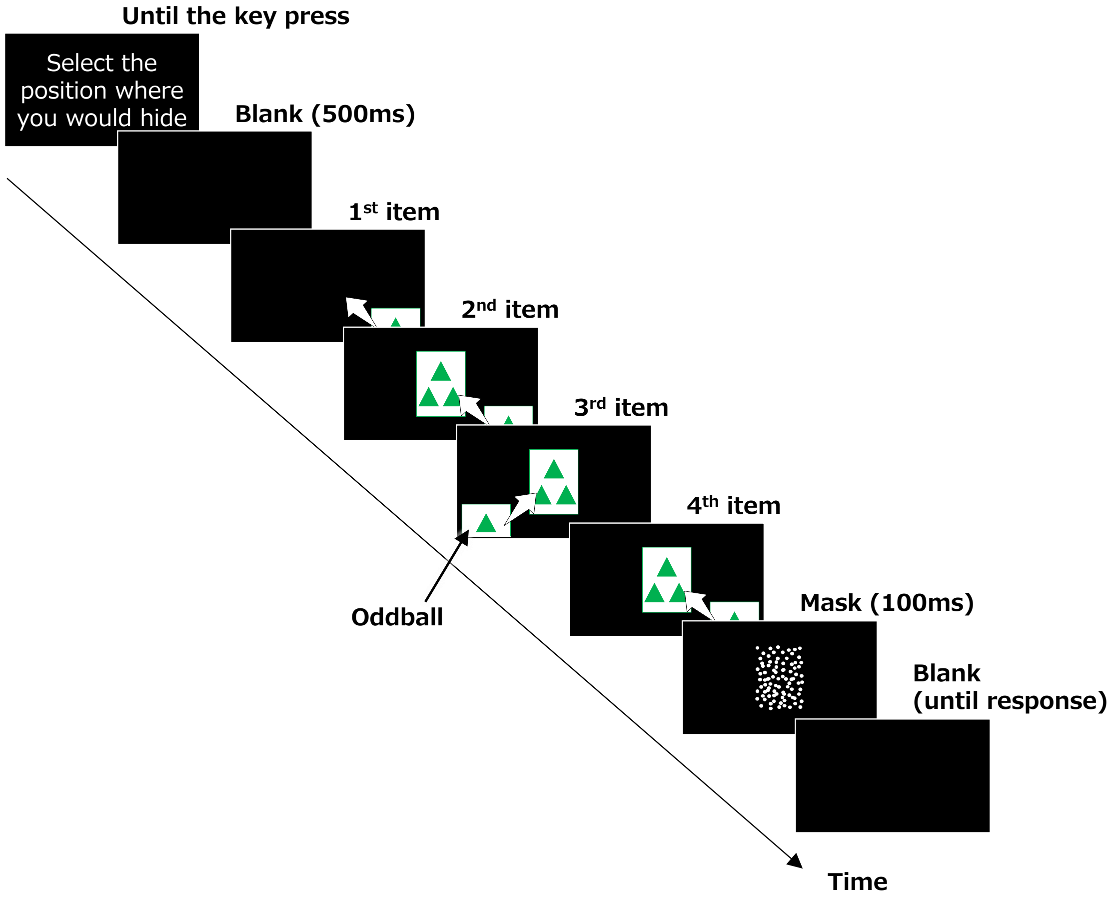

Figure 4. Semantic example of a single trial in the revised hide-find paradigm within the spatiotemporal domain (Experiment 2). All items in the sequence moved from the bottom left or right of the screen to the center of the screen when no oddball was present. When an oddball was present, one of the sequence items moved from the bottom right (or left) of the screen to the center of the screen while the remaining items moved from the bottom left (or right) to the center. In Experiment 2, a random-dot visual mask appeared at the center of the screen for 100 ms after the presentation of the sequence. Following the presentation of visual mask, participants guessed and reported the temporal location of the critical target across partner type (friend or foe) by pressing a corresponding key with no time constraints.

Results

Oddball-present condition. Figure 5 displays the mean frequencies of selecting the oddball item in each temporal position for scenario (hide or seek) and partner type (friend or foe). To determine whether the participants were biased toward oddball items, the frequencies of the oddball selections for scenario and partner type were compared. A two-way ANOVA with scenario as a between-subjects factor and partner type as a within-subject factor was conducted and revealed that the pattern of results obtained in Experiment 1 was replicated in Experiment 2. Specifically, there was a main effect of scenario (F (1, 38) = 7.34, p = .01, η_p^2 = .16), which indicates that the participants more frequently selected the oddball in the seek scenario than the hide scenario. Additionally, the main effect of partner type was significant (F (1, 38) = 155.17, p < .001, η_p^2 = .80), which indicates that the participants more frequently selected the oddball for friends than for foes in both the hide and seek scenarios. The interaction between scenario and partner type was not significant (F (1, 38) = 2.53, p = .12, η_p^2 = .06).

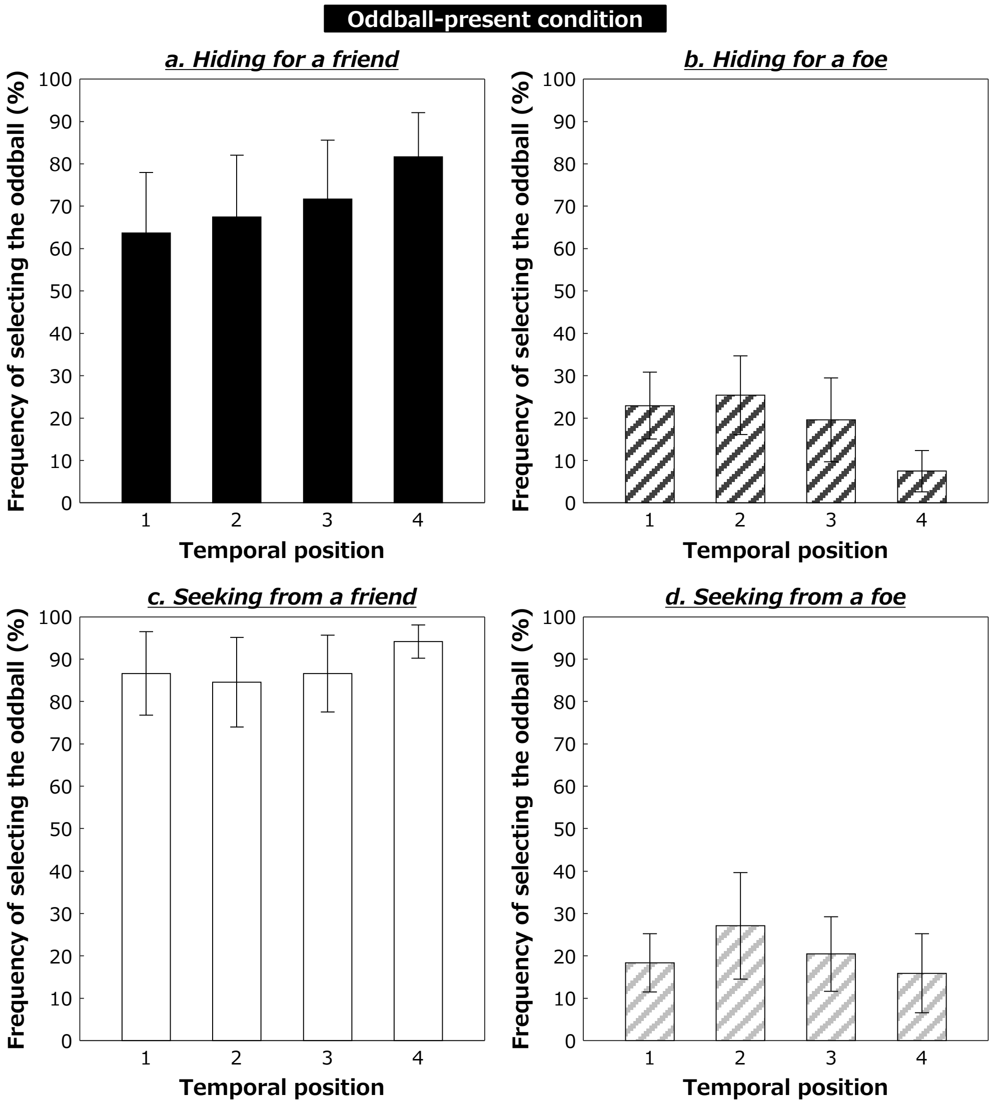

Figure 5. Mean frequencies of selecting the oddball in each temporal position across task scenario (hide or seek) and partner type (friend or foe) in Experiment 2. Error bars show 95% confidence intervals.

Oddball-absent condition. In Experiment 2, the frequencies of the item selections for each task scenario and partner type were compared when the oddball was absent. Chi-square analyses were conducted for each condition to determine whether the temporal positions of the selected items (e.g., first, second, third, or fourth item) were biased. Figure 6 displays the mean frequencies of selecting each of the four temporal positions for each partner type (friend or foe) and scenario (hide or seek). Chi-square tests indicated that the selections in the absence of the oddball were significantly biased by the temporal position when hiding for a friend (Figure 6a, top left; χ^2 (3, N = 480) = 640.20, p < .001, w = 1.16). Specifically, the fourth item was most frequently selected among the items in the various temporal locations (ps < .001). The selection frequencies between the other pairs of locations did not differ (ps > .70).

Next, similar Chi-square tests were conducted to assess the percentages of selections when hiding for a foe and revealed that these selections were significantly biased (Figure 6b, top right; χ^2 (3, N = 480) = 125.70, p < .01, w = 0.51). Specifically, the first and second items were more frequently selected than the third and fourth items (ps < .001). However, the selection frequencies between the first and second items and the third and fourth items did not differ (ps > .38).

In the seek scenario from a friend, Chi-square tests indicated that the selections were significantly biased (Figure 6c, bottom left; χ^2 (3, N = 480) = 378.00, p < .001, w = 0.89) such that the fourth item was selected most frequently among the items (*p*s < .001). The first item was more frequently selected than the second and third items (*p*s < .01) but there was no difference between the second and third items ($p = .12$). When seeking from a foe (Figure 6d, bottom right; χ^2 (3, N = 480) = 115.08, $p < .001$, w = 0.49), the second item was most frequently selected among the items (*p*s < .001) whereas the fourth item was least frequently selected (*p*s < .002). Additionally, the first item was selected more frequently than the third and fourth items (*p*s < .03).

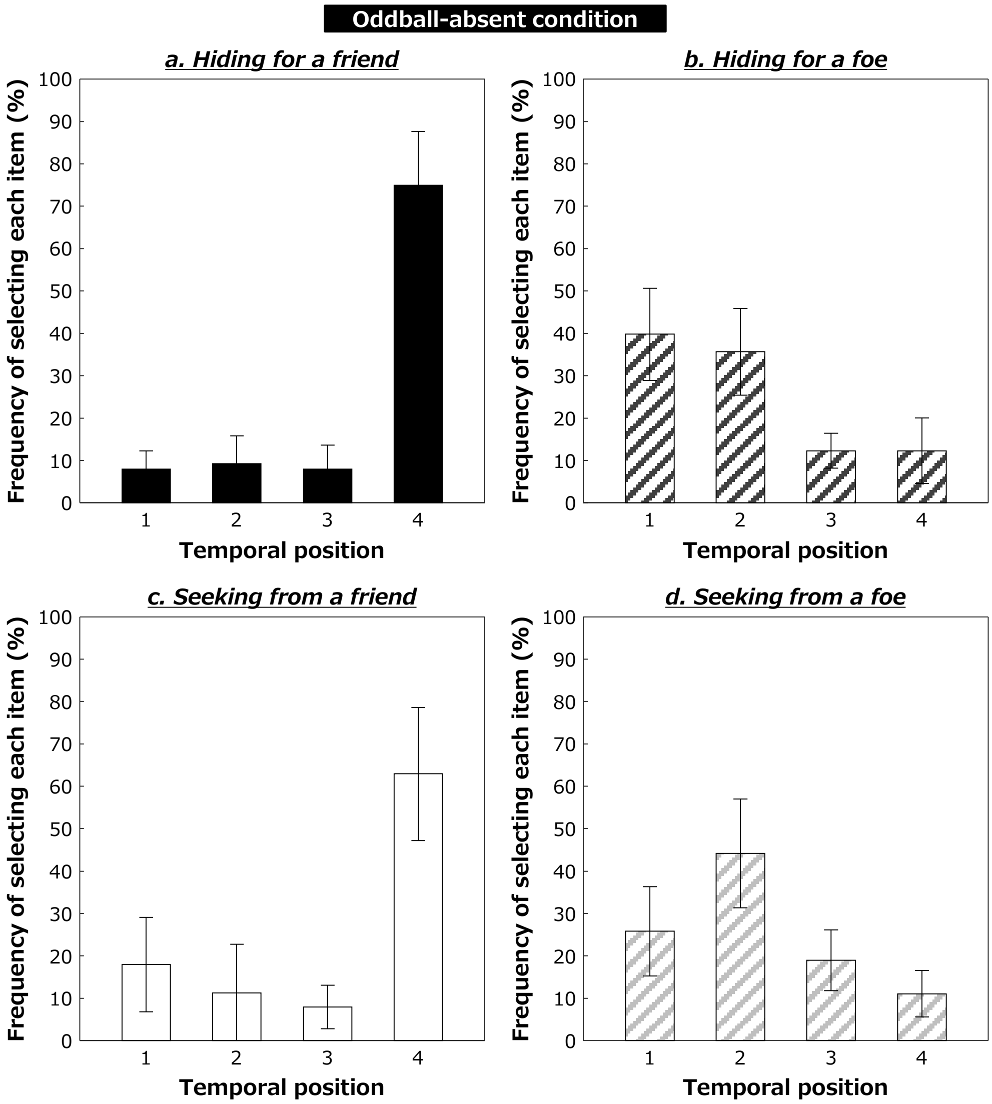

Figure 6. Frequencies of selecting the items in each temporal position under the oddball-absent condition across task scenario (hide or seek) and partner type (friend or foe) in Experiment 2. Error bars show 95% confidence intervals.

Completion times. Experiment 2 also assessed the time required by each participant to make a decision, which was defined as the time from the offset of the mask to the time when a participant selected an item. The median completion times for each participant for each condition (scenario, partner type, and oddball) were calculated (each first trial in the first and second blocks was excluded from analyses of the completion times because these trials were interrupted by an experimenter for task instruction and, thus, we were unable to compare these trials with other trials); the group means of the median completion times are shown in Figure 7. A three-way ANOVA with scenario as a between-subjects factor and partner type and oddball as within-subject factors revealed no main effects of task scenario (F (1, 38) = 0.61, p = .44, η_p^2 = .02) or oddball (F (1, 38) = 0.69, p = .41, η_p^2 = .02). However, the main effect of partner type was significant (F (1, 38) = 19.15, p < .001, η_p^2 = .34), which indicates that completion times were shorter when selecting for friends than when selecting for foes.

Additionally, the interaction among these three factors was significant (F (1, 38) = 9.04, p = .005, η_p^2 = .20). An analysis of the simple-simple main effects of the oddball revealed that completion times were longer under the oddball-absent condition than under the oddball-present condition when searching for a friend (F (1, 19) = 11.56, p = .003, η_p^2 = .38). Moreover, an analysis of the simple-simple main effects of partner type revealed that completion times were longer for foes than friends when hiding (F

(1, 19) = 9.81, $p = .006$, $\eta_p^2 = .34$) and seeking (F (1, 19) = 24.47, $p < .001$, $\eta_p^2 = .56$) in the oddball-present condition.

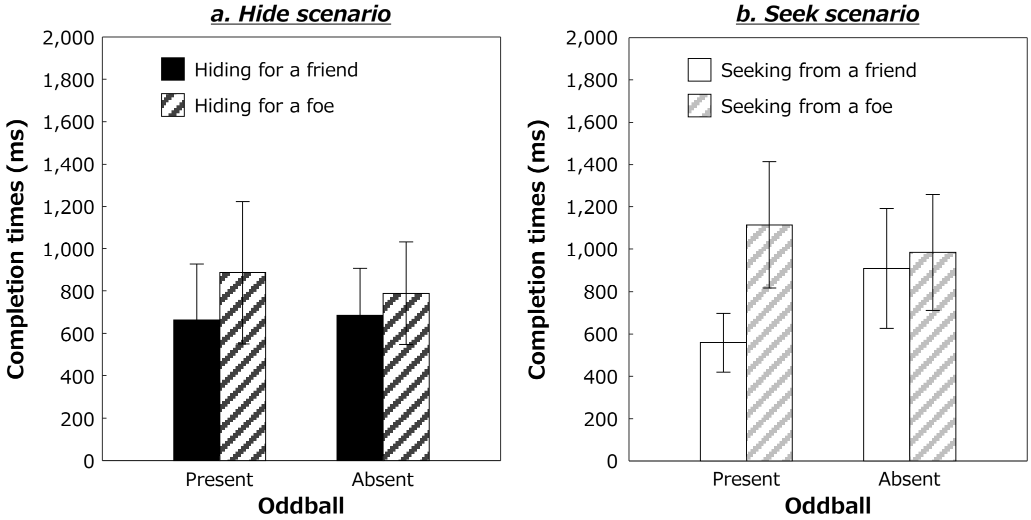

Figure 7. Means of the median completion times across task scenario (hide or seek), partner type (friend or foe), and oddball (present or absent) in Experiment 2. Error bars show 95% confidence intervals.

Discussion

Experiment 2 included a manipulation of visual masking to determine whether the preferential selection of the last (or topmost stacked) item for friends under the non-oddball condition in Experiment 1 was due to physical accessibility or visibility. The results were virtually identical to those of Experiment 1 and, thus, support the physical accessibility hypothesis. Specifically, under the oddball-absent condition, participants most frequently selected the topmost stacked item (e.g., last or fourth item) for friends regardless of whether they were hiding and seeking, whereas they selected the bottommost stacked items (e.g., first or second item) for foes. These results suggest that physical accessibility, such as perception of the ease in reaching for the last item, was critical for the selection rather than temporal factors (e.g., presentation order).

The perceptual visibility of the last item could not explain the present results. Interestingly, in Experiment 2, the frequencies of the last item being chosen for friends (75.0% in the hide condition and 62.9% in the seek condition) were higher than those in Experiment 1 (42.3% in the hide condition and 60.6% in the seek condition). These results indicate that the perceptual visibility of the last item in the absence of the visual mask was not critical when making a selection. Not surprisingly, when the oddball was present, the participants selected the oddball for friends but not for foes, which was consistent with the results of Experiment 1. Taken together, these findings reflect the fundamental principles underlying hiding and finding such that observers will hide or find items for/from friends (or foes) that would (or would not) attract attention.

The completion times when making a decision did not differ between the search and concealment conditions in the present study. This is in sharp contrast to the findings of Anderson et al. (2014) who reported that completion times in the concealment task are longer than those in the search task and suggested that this occurs because concealment is a more complex process than searching. It is possible that this inconsistency between studies is due to the number of items included in the temporal sequence. Anderson et al. (2014) and Street et al. (2018) both included 16 available items in the visual arrays and the completion times in those tasks (approximately 1,000–1,300 ms) were longer than those in the present experiment (approximately 600–1,100 ms). Additionally, the present procedure was designed to assess the spatiotemporal domain and the selections began at the onset of the first item and might not be finished until the offset of the last item in some trials. Nevertheless, longer completion times were observed in the foe condition than in the friend condition in the present study. These findings indicate that the participants utilized more complex strategies for foes than for friends, which is consistent with the results of previous studies showing that performance-based goals and internal motivations increase under competitive circumstances (e.g., Murayama & Elliot, 2012; Tjosvold, Johnson, Johnson, & Sun, 2006).

Thus far, the present results have revealed three major principles involved in the search and concealment of sequentially presented items. First, oddballs, if any, were chosen for friends and avoided for foes. Second, the last item was chosen for friends. Finally, the first item was chosen for foes. Thus, salient items were chosen for friends and avoided for foes regardless of the origin of saliency. In other words, the oddballs in the present study were defined as unique items that differed from the other items in terms of the direction from which they slid into the display; this directional difference made the items more salient compared to the others. When no oddballs were included in the sequence, the first and last items could potentially be salient because they were at the edge of the temporal sequence, i.e., the first item might have been salient because no items preceded it and the last item might have been salient because no items followed it. It should be noted that being the last item, rather than merely the fourth item, is critical. To test this interpretation, Experiment 3 included a manipulation of the number of items in the sequence.

2.4. Experiment 3

Experiment 3 examined the effects of the number of items in the presented sequence on search and concealment. In our opinion, the last item in the sequence is highlighted due to its position and, thus, becomes salient because no items follow it rather than the saliency being due to the item appearing as the fourth item, which represents the upper limits of working memory (Cowan, 2001). Nonetheless, the paradigms employed in Experiments 1 and 2 could not support the interpretation that an item being last and fourth confounded the results. Therefore, in Experiment 3, two more items were included in the sequence. If being presented as the last item in a temporal sequence was critical for the selection, then the last and sixth item would be more frequently selected for friends. Although unlikely, if being the fourth item was critical for the selection, then the fourth item should be more frequently chosen. Additionally, in the present study, it was expected that the number of the items in the sequence would not alter the salience of the initial items and, therefore, the initial items (e.g., first and/or second items) would be more frequently selected for foes.

Method

Participants. A new group of 40 undergraduate and graduate students (16 females, between 18 and 25 years of age) recruited from the participant pool at Hokkaido University participated in exchange for pay or course credit. Half of the participants (eight females; mean age = 20.60 years) were randomly assigned to the hide scenario and the other half (eight females; mean age = 20.20 years) was assigned to the seek scenario.

Apparatus, Stimuli, Design, and Procedure. The apparatus, stimuli, and procedure in Experiment 3 were the same as those used in Experiment 2. However, unlike Experiment 2, the number of items in the sequence was increased from four to six; the duration of the sequence was 4,500 ms (750 ms per card; Figure 8).

In total, the experimental session consisted of 12 blocks and 192 trials. Each block consisted of 16 trials, which included four trials under the oddball-absent condition and 12 trials under the oddball-present condition. The oddball was presented twice in each of the six possible temporal locations of the sequence. The orders of trials under the oddball-present and -absent conditions were randomly determined within each block.

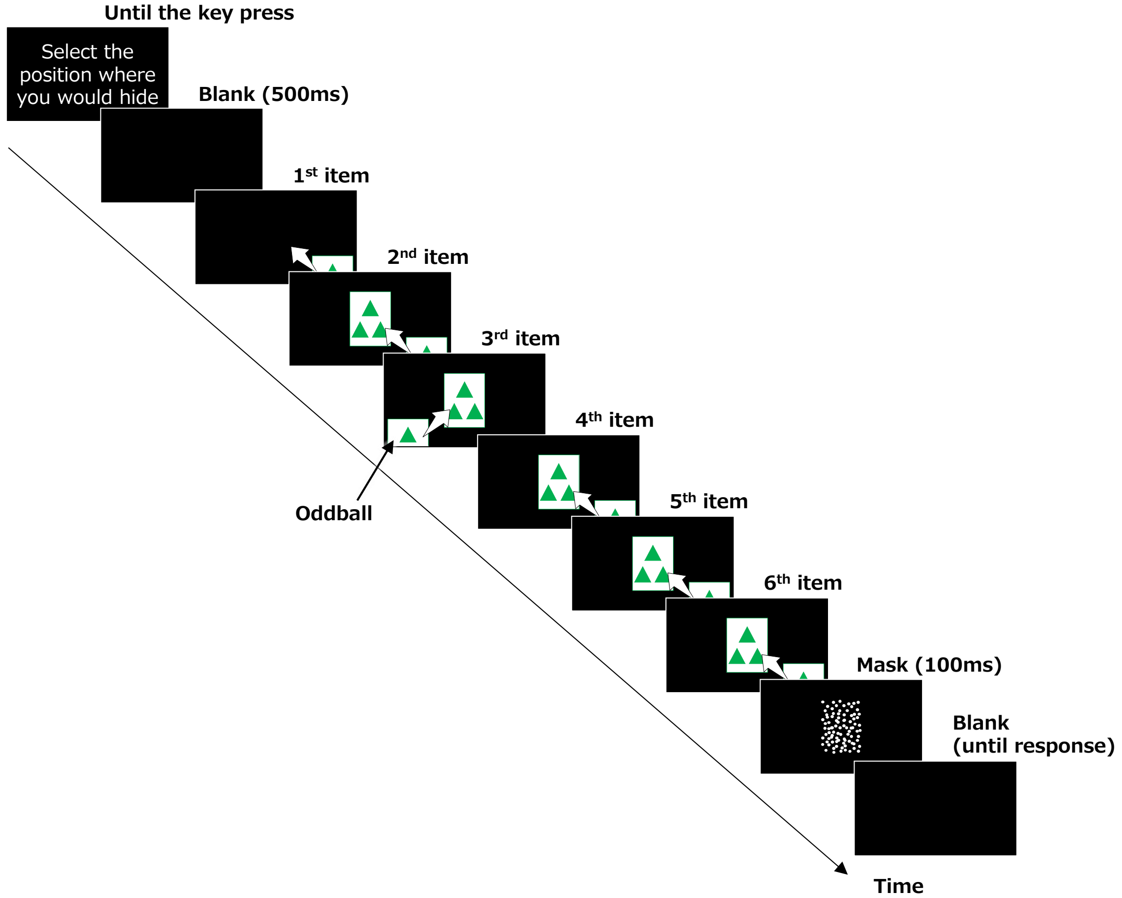

Figure 8. Semantic example of a single trial in the revised hide-find paradigm within the spatiotemporal domain (Experiment 3). All items in the sequence moved from the bottom left or right of the screen to the center of the screen when no oddball was present. When an oddball was present, one of the sequence items moved from the bottom right (or left) of the screen to the center of the screen while the remaining items moved from the bottom left (or right) to the center. In Experiment 3, a random-dot visual mask appeared at the center of the screen for 100 ms after the presentation of the sequence. Following the presentation of the visual mask, participants guessed and reported the temporal location of the critical target across partner type (friend or foe) by pressing a corresponding key with no time constraints.

Results

Oddball-present condition. Figure 9 displays the mean frequencies of selecting the oddball item in each temporal position for scenario (hide or seek) and partner type (friend or foe). To determine whether participants were biased toward the oddball items, the frequencies of selecting the oddball for task scenario and partner type were compared. A two-way ANOVA with scenario as a between-subjects factor and partner type as a within-subject factor revealed that the main effect of scenario was not significant (F (1, 38) = 1.66, p = .21, η_p^2 = .04). However, the main effect of partner type was significant (F (1, 38) = 156.26, p < .001, η_p^2 = .80), which indicates that participants more frequently selected the oddball for friends but not foes in both the hide and seek scenarios. The interaction between scenario and partner type was also significant (F (1, 38) = 4.20, p = .05, η_p^2 = .10). An analysis of the simple-main effects revealed that the frequency of selecting an oddball in the friend context tended to decrease when participants engaged in the hide scenario relative to when they engaged in the seek scenario (F (1, 38) = 4.10, p = .051, η_p^2 = .10). However, no such trend was observed in the foe context (F (1, 38) = 1.21, p = .28, η_p^2 = .03).

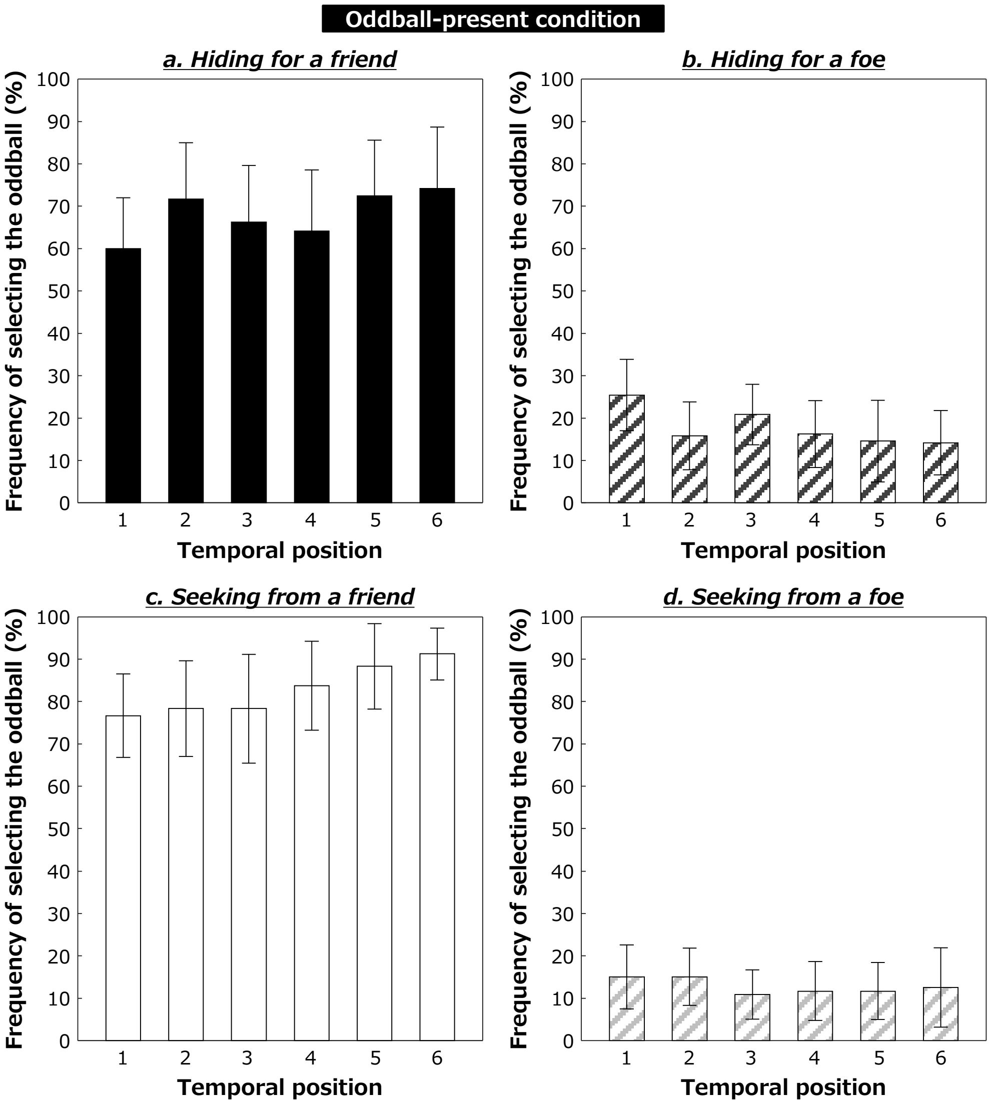

Figure 9. Mean frequencies of selecting the oddball in each temporal position across task scenario (hide or seek) and partner type (friend or foe) in Experiment 3. Error bars show 95% confidence intervals.

Oddball-absent condition. The frequencies of the item selections for task scenario and partner type when the oddball was absent were compared and Chi-square analyses for each condition were conducted to determine whether the positions of the selected items (e.g., first, second, third, fourth, fifth, or sixth item) were biased. Figure 10 displays the mean frequencies of selecting each one of the six temporal positions for partner type (friend or foe) and scenario (hide or seek). Chi-square tests revealed that the selections in the absence of the oddball were significantly biased by temporal position when hiding for a friend (Figure 10a, upper left; χ^2 (5, N = 480) = 742.33, p < .001, w = 1.24), which indicates that the sixth item was most frequently selected among all items (ps < .001). The first item was the second most frequently selected item relative to the others (ps < .001) but the selections of the items in the remaining temporal positions (i.e., second, third, fourth, and sixth items) did not differ (ps > .07).

Similar Chi-square tests were applied to assess the probabilities of selections when hiding for a foe and revealed a significant effect of temporal position (Figure 10b, top right; χ^2 (5, N = 480) = 38.24, p < .001, w = 0.28). Specifically, the first item was most frequently selected relative to other items (ps < .05) and the second and third items were more frequently selected than the fifth item (ps < .04). No differences were observed between the remaining pairs of items (ps > .06).

When seeking from a friend, Chi-square tests revealed that selections were significantly biased (Figure 10c, bottom left; χ^2 (5, N = 480) = 905.77, p < .001, w =

1.37) such that the sixth item was most frequently selected relative to the other items (*p*s < .001). The first item was the second most frequently selected item (*p*s < .003) and the third item was more frequently selected than the second or fifth items (*p*s < .004). There were no differences in the selection frequencies between the remaining pairs (*p*s > .12).

Finally, the same Chi-square tests were applied to the seeking from a foe condition and revealed a significant effect of temporal position (Figure 10d, bottom right; χ^2 (5, *N* = 480) = 36.97, *p* < .001, *w* = 0.28). Specifically, the first and second items were more frequently selected than the other items (*p*s < .05), the third item was more frequently selected than the sixth item (*p* = .05), and the fifth item was more frequently selected than the sixth item (*p* = .02). There were no differences in selection frequencies between the other pairs of comparisons (*p*s > .21).

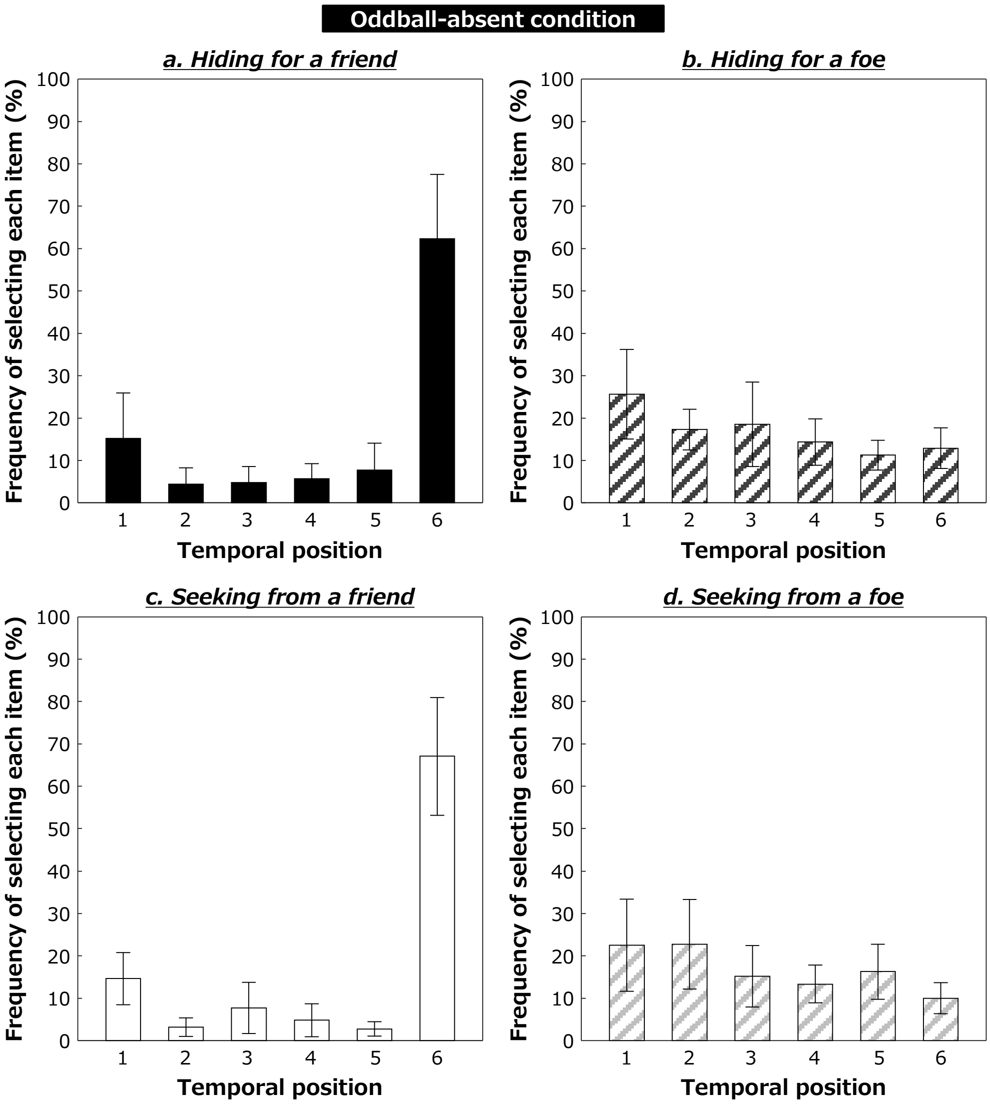

Figure 10. Frequencies of selecting the items in each temporal position under the oddball-absent condition across task scenario (hide or seek) and partner type (friend or foe) in Experiment 3. Error bars show 95% confidence intervals.

Completion times. The median completion times for each participant, which were calculated from the offset of the mask until a participant selected an item, were compared across the conditions (scenario, partner type, and oddball). Figure 11 shows the group means of the median completion times in Experiment 3. A three-way ANOVA with scenario as a between-subjects factor and partner type and oddball as within-subject factors revealed a marginally significant main effect of scenario (F (1, 38) = 3.96, p = .054, η_p^2 = .09), which indicates that the completion times when hiding were longer than when seeking. Significant main effects were also found for oddball (F (1, 38) = 17.74, p < .001, η_p^2 = .32) and partner type (F (1, 38) = 28.61, p < .001, η_p^2 = .43). The former result indicated that the completion times in the oddball-present condition were shorter than in the oddball-absent condition. The latter result indicated that the completion times were shorter during selections for friends than for foes. No interaction effects were observed among the factors for completion times (Fs (1, 38) < 1.44, ps > .24, η_p^2 < .04).

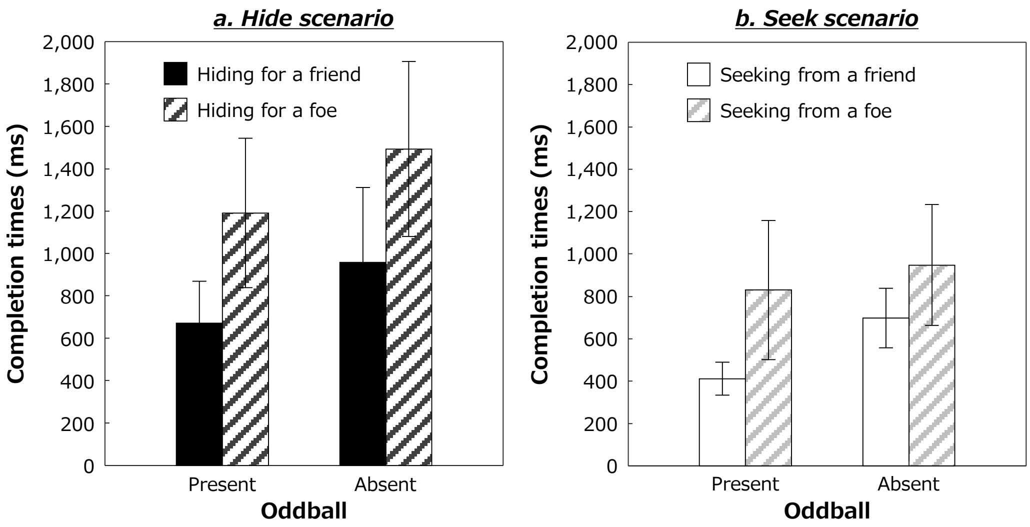

Figure 11. Means of the median completion times across task scenario (hide or seek), partner type (friend or foe), and oddball (present or absent) in Experiment 3. Error bars show 95% confidence intervals.

Discussion

In Experiment 3, when the sequence did not contain an oddball, the last (sixth) item was more frequently selected for friends in both scenario types. This result indicates that the last item in the temporal sequence was critical during selection for a friend rather than the fourth item being most critical. Additionally, the initial items (i.e., first and second items) were more frequently selected for foes under the oddball-absent condition, which was identical to the results obtained in Experiments 1 and 2. In all three experiments, the saliencies of the initial items were similar regardless of the number of the items in the sequence. Taken together, these results support the physical accessibility hypothesis. However, for friends, the initial (first) items were selected relatively more frequently under both scenarios, which indicates that the participants continued to employ strategies that assumed that the first item would attract attention relative to other items. As expected, the results from the oddball-present condition were identical to the results of the previous experiments in that participants selected the oddball for friends but not foes. This result demonstrates the fundamental principles underlying hiding and finding, which indicate that observers will hide or find items from friends (or foes) that would (or would not) attract attention.

The present results for completion times in the task scenarios differed from those observed in Experiment 2. Specifically, in Experiment 3, the completion times in the hide scenario were longer than those in the seek scenario whereas these differences were not observed in Experiment 2. This finding is consistent with those of Anderson et al. (2014) and suggests that hiding involves more complex strategies than seeking. In contrast, effects similar to those observed in Experiment 2 were obtained for partner type in Experiment 3. Specifically, there was a longer completion time for foes than for friends, which is likely to indicate that the participants used more complex strategies for foes than for friends. This pattern of results is consistent with those of previous studies (e.g., Murayama & Elliot, 2012; Tjosvold et al., 2006) in that performance-based goals or internal motivations increase under competitive circumstances. Finally, there were longer completion times in the non-oddball condition than the oddball condition, which indicates that the fixed strategies used in the oddball condition led to faster decisions because the selections in this condition were dominant.

2.5. Experiment 4

The final experiment in this chapter included a manipulation of the direction of the stacking order to determine whether perceptual accessibility would be susceptible to the stacked order of the items. Specifically, the items in Experiment 4 were stacked downward whereas the items in Experiments 1–3 were stacked in an upward direction; therefore, the first (or last) items were the topmost (or bottommost) stacked items in Experiment 4. If the topmost stacked item (e.g., first item) was frequently selected for friends and the bottommost stacked item (e.g., fourth item) was frequently selected for foes, then the explanation based on physical accessibility would be supported regardless of the order of the stack.

Method

Participants. A new group of 40 undergraduate and graduate students (13 females, between 18 and 24 years of age) recruited from the participant pool at Hokkaido University participated in exchange for pay or course credit. Half of the participants (seven females; mean age = 19.75 years) were randomly assigned to the hide scenario and the other half (six females; mean age = 20.60 years) was assigned to the seek scenario.

Apparatus, Stimuli, Design, and Procedure. In Experiment 4, the apparatus, stimuli, and design were the same as those used in Experiment 2. However, whereas each card was stacked upwards in Experiments 1–3, the participants indicated where they would hide or find an item in a temporal sequence of cards in which each card was stacked downwards in Experiment 4. Using this type of visualization, it was not possible to visually recognize new cards stacked in the bottommost layer because they closely overlapped. To avoid ambiguity during interpretation of the stacked order, the participants were explicitly instructed before the experiment that the newly presented card would be placed underneath the bottommost card of the previously stacked items.

Results

Oddball-present condition. Figure 12 displays the mean frequencies of selecting the oddball item in each temporal position for partner type (friend or foe) and task scenario (hide or seek). To determine whether the participants were biased towards selection of the oddball items, the frequencies of selecting the oddball in the task scenario and partner type conditions were compared. A two-way ANOVA with task scenario as a between-subjects factor and partner type as a within-subject factor revealed a significant main effect of task scenario (F (1, 38) = 13.08, $p < .001$, $\eta_p^2 = .26$), which indicates that the participants more frequently selected the oddball in the seek scenario than the hide scenario. Additionally, the main effect of partner type was significant (F (1, 38) = 107.89, $p < .001$, $\eta_p^2 = .74$), which indicates that participants selected the oddball in both the hide and seek scenarios for friends but not foes.

The interaction between task scenario and partner type was also significant (F (1, 38) = 9.08, $p = .005$, $\eta_p^2 = .19$). An analysis of the simple-main effects revealed that the frequency of selecting an oddball in the friend context significantly decreased when participants engaged in the hide scenario compared to when they engaged in the seek scenario (F (1, 38) = 12.87, $p < .001$, $\eta_p^2 = .25$). However, no such effect of task scenario was observed in the foe condition (F (1, 38) = 0.30, $p = .59$, $\eta_p^2 = .01$).

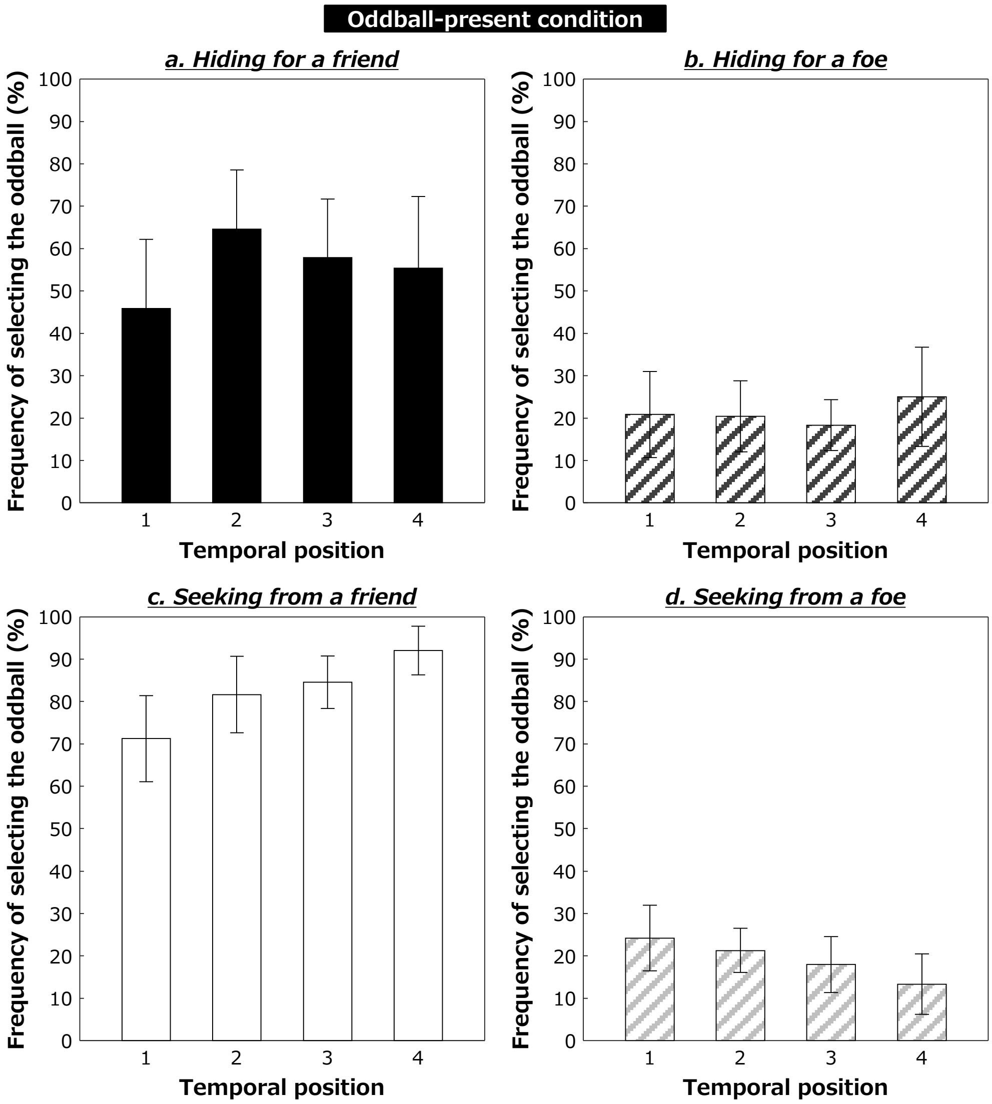

Figure 12. Mean frequencies of selecting the oddball in each temporal position across task scenario (hide or seek) and partner type (friend or foe) in Experiment 4. Error bars show 95% confidence intervals.

Oddball-absent condition. The selection frequencies for task scenario and partner type when the oddball was absent were compared and Chi-square analyses for each condition were conducted to determine whether the positions of the selected items (e.g., first, second, third, or fourth item) were biased. Figure 13 displays the mean frequencies of selecting one of the four temporal positions across partner type (friend or foe) and task scenario (hide or seek). Chi-square tests revealed that the selections in the absence of the oddball were significantly biased by temporal position when hiding for a friend (Figure 13a, top left; χ^2 (3, N = 480) = 77.22, p < .001, w = 0.40). Specifically, the first item was most frequently selected compared to the other items (ps < .001) and the second item was more frequently selected than the third and fourth items (ps < .008). The selection frequencies between the third and fourth items did not differ (p = .07).

Similar Chi-square tests were applied to assess the probabilities of selections when hiding for a foe and revealed a significant effect of temporal position (Figure 13b, top right; χ^2 (3, N = 480) = 14.55, p < .01, w = 0.17). Specifically, the fourth item was more frequently selected than the second and third items (ps < .03) but the selections between the first and fourth items did not differ (p = .40). The first item was more frequently selected than the third item (p = .03). However, the selection frequencies between the first and second items (p = .21) and between the second and third items (p = .39) did not differ.

In the seek scenario from a friend, Chi-square tests revealed that the selections were significantly biased (Figure 13c, bottom left; χ^2 (3, N = 480) = 324.28, $p < .001$, w = 0.82), which indicates that the first item was more frequently selected than the other items (ps < .001). Additionally, the fourth item was more frequently selected than the second and third items (ps < .001) but there was no difference in the selection frequencies between the second and third items (p = .41).

Finally, the same Chi-square tests were applied to the seeking from a foe condition and revealed a significant effect of temporal position (Figure 13d, bottom right; χ^2 (3, N = 480) = 32.92, $p < .001$, w = 0.26), which indicates that the second item was more frequently selected than the fourth item ($p < .001$). However, the selection of the second item did not differ from those of the first and third items (ps > .10). The fourth item was selected least frequently among all items (ps < .001).

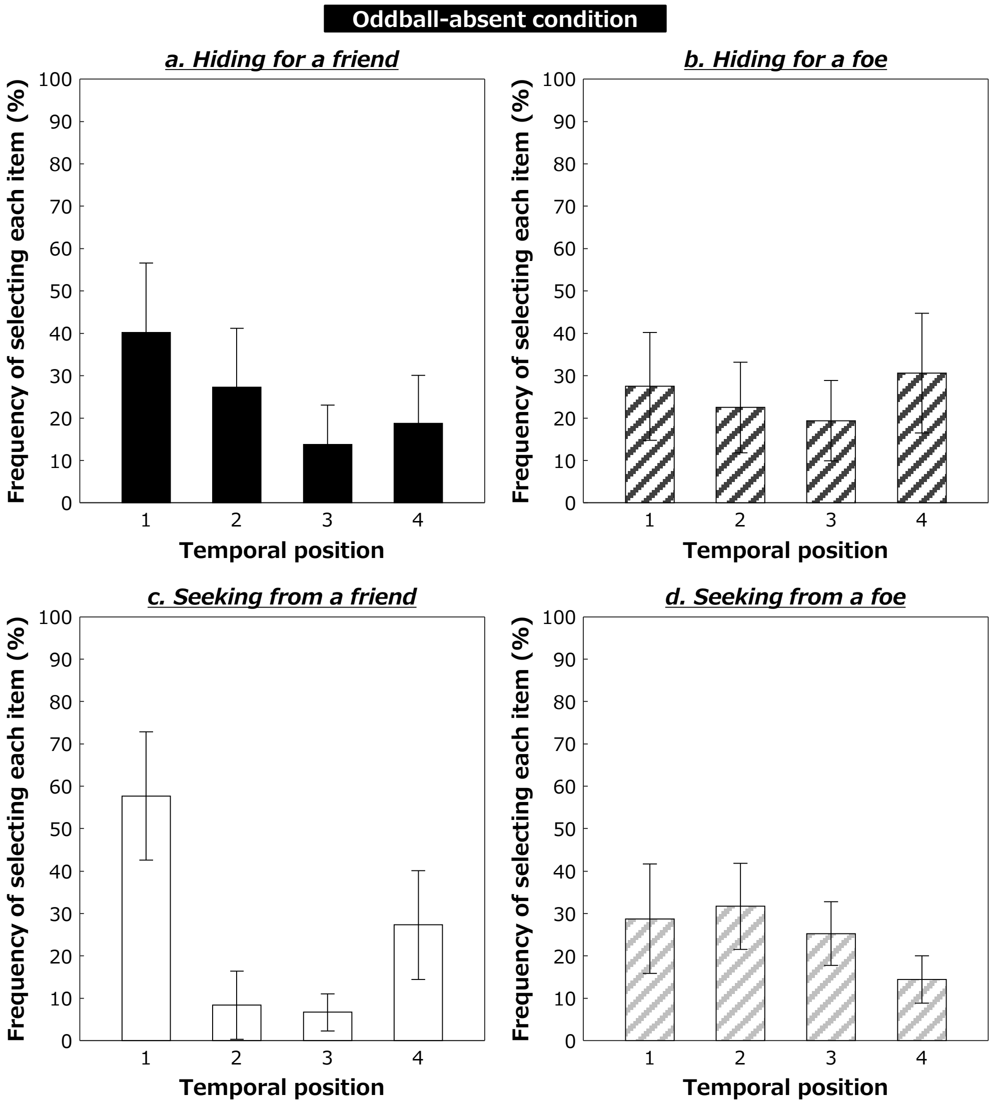

Figure 13. Frequencies of selecting the items in each temporal position under the oddball-absent condition across task scenario (hide or seek) and partner type (friend or foe) in Experiment 4. Error bars show 95% confidence intervals.

Completion times. The completion times in Experiment 4 were compared across conditions; Figure 14 shows the group means of the median completion times. A three-way ANOVA with scenario as a between-subjects factor and partner type and oddball as within-subject factors revealed no main effects of scenario (F (1, 38) = 0.26, p = .61, η_p^2 = .01) and oddball (F (1, 38) = 0.46, p = .50, η_p^2 = .01). The main effect of partner type was significant (F (1, 38) = 17.38, p < .001, η_p^2 = .31), which indicates that the response times were shorter for selections for friends than for foes. The interaction among the three factors was also significant (F (1, 38) = 6.98, p = .01, η_p^2 = .16) and an analysis of the simple-simple main effects of the oddball factor revealed that the completion times were longer on trials in the oddball-absent condition than in the oddball-present condition when searching for items for a friend (F (1, 19) = 6.86, p = .02, η_p^2 = .27) whereas the completion times were shorter on trials in the oddball-absent condition than in the oddball-present condition when searching for items for a foe (F (1, 19) = 8.25, p = .01, η_p^2 = .30). Moreover, an analysis of the simple-simple main effect of partner type revealed that the completion times were longer for a foe than for a friend when seeking in the oddball-absent condition (F (1, 19) = 28.90, p < .001, η_p^2 = .60).

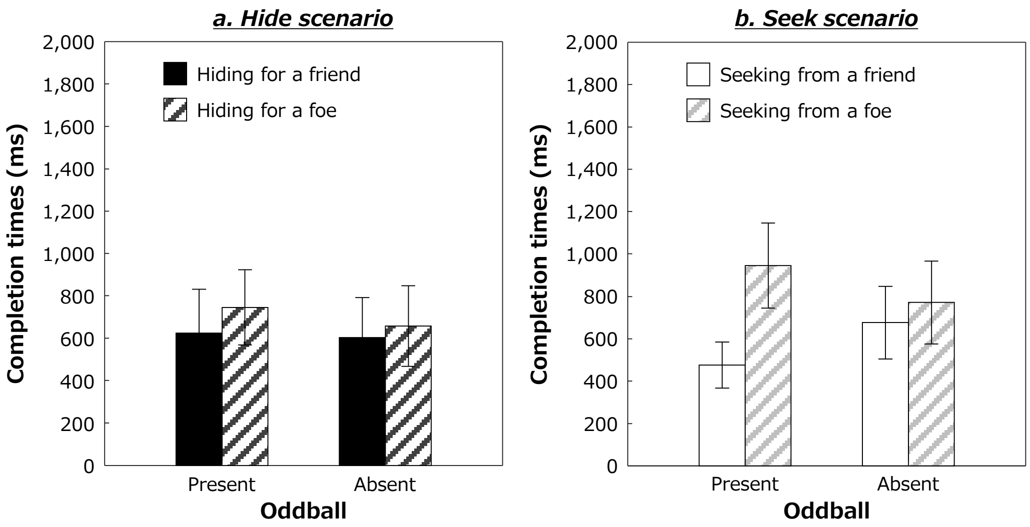

Figure 14. Means of median completion times across task scenario (hide or seek), partner type (friend or foe), and oddball (present or absent) in Experiment 4. Error bars show 95% confidence intervals.

Discussion

The results of Experiment 4 supported the physical accessibility hypothesis only when hiding and seeking items for/from a friend. Specifically, when an oddball was absent, the topmost stacked item (i.e., the item presented first in the sequence) was more frequently selected for friends regardless of whether the scenario was hiding or seeking, which reflects the perception of ease when reaching for items. However, perceptual accessibility did not predict the behaviors of the participants when hiding and seeking for/from a foe. The fourth item (i.e., the bottommost stacked item) should have been most frequently selected relative to the other items (e.g., first item) if the participants chose items based on physical accessibility. However, the present results revealed that the first and fourth items were more frequently selected when hiding for a foe. Moreover, the present results differed from those of previous experiments when seeking from a foe. In the present study, the top-layered items (i.e., the first and second items) were more frequently selected than the bottommost stacked item (i.e., the fourth item). Intuitively, the first item should attract strong attention because it remained in view and, thus, was continually attended to during the presentation of the temporal sequence. One possible explanation for this finding is that perceptual accessibility was applied to the concealment and search strategies for friends. In contrast, observers would apply these strategies based on temporal order, such as temporal remoteness, because the first (or second) item was frequently selected for foes regardless of the stacked order. Therefore, two different strategies appear to have been applied based on partner type, i.e., observers applied search and concealment strategies for friends based on spatial factors, such as physical accessibility, whereas they applied strategies based on temporal factors, such as remoteness in time, for foes.

Not surprisingly, in the oddball-present condition, participants most frequently selected the oddball for friends whereas they avoided selecting the oddball for foes. These results are identical to previous findings (e.g., Anderson et al., 2014) and suggest that there are fundamental principles associated with hiding and finding. The completion time results in Experiment 4 were almost the same as those obtained in Experiment 2. Additionally, longer completion times were observed in the foe context than in the friend context, which suggests that the participants applied more complex strategies for foes than for friends.

2.6. Summary of Findings

The purpose of the present chapter was to expand upon previous findings in the spatial domain (e.g., Anderson et al., 2014; Street et al., 2018) by examining search and concealment strategies in the spatiotemporal domain, to determine whether observers would indicate where they would find or hide a target within a temporal sequence. The hide-find paradigm was initially introduced to investigate search and concealment strategies in the spatiotemporal domain, in which items appear sequentially and are stacked; the present study manipulated partner type and the presence or absence of an oddball using this sequencing. When the sequence of items contained the oddball, participants were most likely to select the oddball for/from a friend whereas they avoided the oddball for/from a foe. The present results were consistent with the fundamental principles of search and concealment observed in the spatial domain (Anderson et al., 2014; Street et al., 2018) and further suggest that these principles were applied to the present spatiotemporal task involving search and concealment. However, in contrast to previous findings, the present results from all experiments showed that the selection frequencies of the oddball in the seek scenario were higher than in the hide scenario. This indicates that participants made more complex estimations in the hide scenario than in the seek scenario.

Importantly, the present study focused on situations in which participants indicated where they would hide or find a target within a temporal sequence of items when the oddball was absent. It was expected that under such conditions either the spatial principles associated with hiding and seeking (Anderson et al., 2014) or the biases based on serial presentation effects (recency or primacy) would be reflected in the selections. If the principle or biases were applied to spatiotemporal search and concealment, then the first and last items would be more frequently selected for/from a friend whereas the remaining items would be more frequently selected for/from a foe. However, no such trends were observed in any of the experiments. Rather, the present results revealed the two following distinct search and concealment strategies that differed dramatically, depending on partner type: observers selected targets based on (1) physical accessibility in the friend context and (2) temporal remoteness in the foe context. For the former strategy, observers selected targets based on the perception of ease of reaching for the stacked items; more specifically, observers selected the topmost item of the stacked stimuli. For the latter strategy, observers selected items that appeared in relatively early temporal positions. These strategies were consistently employed in the present search and concealment tasks regardless of whether visual masking was applied after visual exposure to the last item, the number of items in the sequence, and stack direction.

In terms of completion times, a main effect of partner type was consistently observed in all experiments, which indicates that the response times were shorter for selections for friends than for foes. This result suggests that observers made more complex estimations in the foe context than in the friend context. In Experiments 2 and 4, when observers were seeking from a foe, the response times were shorter in trials during the oddball-present condition than during the oddball-absent condition. In Experiment 3, there was a main effect of the oddball, which indicates that the observers estimated the target position more quickly when the oddball was present than when the oddball was absent. These effects of the oddball on response times are reasonable because the selections of the oddball, especially in the friend context, were fixed in the results of the selection frequencies and were made intuitively. Finally, increasing the number of items in the sequence (Experiment 3) resulted in slower response times, especially when hiding. In fact, the response times were longer in trials in the hide scenario than in the seek scenario; no such trend was observed in the other experiments in the present study.

CHAPTER 3. SEARCH AND CONCEALMENT STRATEGIES IN THE TEMPORAL DOMAIN

3.1. Overview

In Chapter 2, hiding and finding strategies in the spatiotemporal domain have been explored and this was accomplished by modifying the hide-find paradigm developed by Anderson et al. (2014). This paradigm presents situations in which items appear in sequential order (e.g., a suit of flipped playing cards) and are then stacked while the task is manipulated in terms of scenario (hide or seek) and partner type (friend or foe). More specifically, participants view a temporal sequence of items and then either hide or search for a target. If participants hide a target from a friend (or a foe), then they indicate a temporal location so that the friend (or foe) would (or would not) find it. If participants seek a target hidden by a friend (or foe), so that they would (or would not) find it, then they indicate the temporal location of the target. Furthermore, in this hide and seek task, an oddball can be presented as a cue that can attract attention and play a critical role during target selection. For example, when participants, engaged in a hiding or finding task in the friend context, are presented with an oddball, they are more likely to select the oddball. However, when the oddball is present while the participants are engaged in tasks in the foe context, they avoid selecting the oddball. These results suggest that the oddball is more likely to be selected in the spatial (Anderson et al., 2014; Street et al., 2018) and spatiotemporal (Chapter 2) domains of search and concealment tasks. Thus, based on their intuitions, participants are likely to believe that the oddball would attract attention due to its salience and search efficiency (Smilek et al., 2009). This would make it readily discoverable for a friend, which indicates that the fundamental principles of search and concealment are reflected in the selection.

Importantly, principles unique to spatiotemporal search and concealment behaviors have been observed when the oddball is absent, in Chapter 2. For example, search and concealment strategies dramatically differ depending on partner type. More specifically, when participants acknowledge that one's partner is a foe, they are more likely to select items presented earlier (generally the first item in a sequence). It has been argued that these selections are based on temporal remoteness rather than serial position effects (e.g., primacy and recency effects; Grenfell-Essam & Ward, 2012; Murdock Jr, 1962) in which participants bias earlier positions as being non-salient. However, when participants acknowledge that one's partner is a friend, these temporal factors are not reflected in their selections. It is possible that the selections based on spatial factors occur because the sequentially presented items are stacked after being exposed to the participants. To investigate the effects of the spatial structure of stacked items, the stacked order was manipulated so that newly appeared items were placed over (or under) the old items, in Chapter 2. The results revealed that participants are more likely to select the topmost items of stacked stimuli regardless of the stacked order. That is, for items for/from a friend, participants determine the target location based on physical accessibility according to the supposed perception of ease of reaching. Therefore, search and concealment principles specific to the spatiotemporal domain rather than the temporal domain, were observed in Chapter 2.

In Chapter 3, hiding and finding strategies were investigated in a *purely* temporal domain by eliminating spatial factors associated with the presented items to determine whether participants would indicate where they would hide or search for a target item within a temporal sequence of items under a variety of circumstances. To eliminate spatial factors related to the items in Chapter 2, they immediately faded out after they appeared in the present chapter. The present study also manipulated partner type in terms of social context (friend or foe, i.e., the interpersonal relationship between the participant and a fictional opponent) as well as the presence or absence of an oddball.

The present study placed a particular focus on conditions in which participants engaged in the hide or seek task when the oddball was absent and predicted that there would be fewer selections based on physical accessibility because the present procedure eliminated the spatial factors related to the presentations of items. However, temporal remoteness could be still applied to the selections in these conditions because this bias would occur regardless of the presence or absence of spatial factors.

Specifically, if the temporal remoteness that was observed in the spatiotemporal domain (i.e., participants are biased to perceive the selection of temporally earlier items as non-salient) is critical for selections in the present paradigm, then participants would hide or search for later (or earlier) items for/from a friend (or a foe). However, if serial presentation effects (e.g., the primacy and recency effects; Grenfell-Essam & Ward, 2012; Murdock Jr, 1962) are critical for the selections in the present paradigm (e.g., temporal domain), then the first and last items would be selected for a friend whereas the remaining items would be selected for a foe.

To investigate these selection biases, the present study included three experiments using the same procedures as Chapter 2. Experiment 5 examined these biases when the last item was not masked. In Experiment 6, visual masking occurred after the presentation of the last item to distinguish the selection biases obtained in Experiment 1 from biases based on conceptual processing (Intraub, 1984; Potter, 1976; Potter & Levy, 1969) or the suffix effect (Baddeley & Hull, 1979; Parmentier et al., 2004), which refers to a reduction in the recency effect due to the presentation of task-irrelevant items after the last item. Finally, Experiment 7 examined the effects of the number of items in the temporal sequence on the selection biases. The following prediction was made for all experiments: when an oddball was present, the participants would be more likely to select the oddball for/from a friend whereas they would avoid selecting the oddball for/from a foe. This is due to the fundamental principle of search and concealment in which observers estimate that the salient (or non-salient) item should (or should not) attract attention for/from friends (or foes).

3.2. Experiment 5

Experiment 5 aimed to determine the locations where participants would choose to hide or search for a target within a purely temporal sequence of non-stacked items while manipulating partner type (e.g., a fictional opponent who was a friend or foe) and the presence or absence of an oddball (e.g., a unique item in the temporal sequence). In the present task, participants viewed a temporal sequence of four items as if a suit of flipped playing cards appeared sequentially. Each item appeared one after another, faded out immediately after presentation, and was followed by the appearance of a subsequent item to avoid the impression that the cards were stacked. Next, the participants selected a target position across task scenario (hide or seek) and partner type (friend or foe). If the temporal remoteness hypothesis is critical for selections when the oddball is absent, then participants would more frequently select earlier presented items for/from a friend and more frequently select later presented items for/from a foe. However, if selections are biased by serial position effects, then participants would select the first and last items for/from a friend and the second and third items for/from a foe. When the oddball was present, it was predicted that the oddball would be more frequently selected than non-oddballs when the participants acknowledged that one's partner was a friend whereas they would avoid selecting the oddball when the partner was a foe.

Method

Participants. Forty undergraduate and graduate students (11 females, between 18 and 26 years of age) from the participant pool at Hokkaido University participated for pay or in exchange for course credit. Half of the participants (five females, mean age = 20.30 years) were randomly assigned to the hide scenario, and the remaining half (six females, mean age = 20.25 years) were assigned to the seek scenario. All participants in this and the subsequent experiments reported normal or corrected-to-normal visual acuity and provided written informed consent according to approval by the Center for Experimental Research in Social Sciences of Hokkaido University.

Apparatus and Stimuli. Stimuli were presented on a LCD monitor (24-inch, 1,920 × 1,080 pixels) with 100 Hz of refresh rate controlled by a PC/AT-compatible computer operating with Linux, Matlab, and Psychophysics Toolbox 3 (Brainard, 1997; Kleiner et al., 2007; Pelli, 1997). Stimuli were displayed on a black background. The viewing distance was approximately 57 cm. Responses were collected via a keyboard connected to the computer. Participants viewed a sequence of four white-colored items with green-colored patterns that looked like back of playing cards (Figure 15). Each item (card) subtended 22.3° in height and up to 15.0° in width.

Design. Experiment 5 employed a 2 × 2 × 2 factorial design that included one between-subjects factor of task scenario (hide or seek) and two within-subject factors of partner type (social context: friend or foe) and oddball (present or absent). Overall, the experimental session consisted of 12 blocks of 12 trials, which resulted in a total of 144 trials. Half of the blocks were assigned to the friend context and the remaining half of blocks were assigned to the foe context. The order of partner type alternated between contexts, and the initial context (friend or foe) was counterbalanced within each task scenario group. In each block of 12 trials, four trials were under the oddball-absent condition and eight trials were under the oddball-present condition. The oddball was presented twice in each of the four possible temporal locations and the order of trials was randomly determined within each block.

Procedure. In each block, the instructions were presented across task scenario and partner type such that participants were asked to indicate where they would hide or find an item in a temporal sequence of cards after acknowledging that a partner was a friend or foe (Table 1). Under the hide scenario for a friend (or a foe), participants were told to select a temporal position to conceal an item so that the friend could choose it (or the foe could not choose it). Under the seek scenario for a friend (or a foe), participants were told to select a temporal position to pick to an item hidden by a friend (or a foe) so that each participant would find it (or so that the participants would not find it).

Each trial began with the presentation of written instructions in the center of a screen and then participants initiated the trial by pressing the space bar. After a blank screen was presented for 500 ms, the temporal sequence began with each item appearing for 750 ms and then fading out after 450 ms; there was no inter-stimulus interval. When the oddball was absent, all items moved from the bottom-right (or bottom-left) to the center of the screen. When the oddball was present, three of the four items moved from the bottom-right (or bottom-left) to the center of the screen while one item moved from the bottom-left (or bottom-right) to the center of the screen. The direction from which an oddball slid onto the screen was counterbalanced across trials and the items faded out immediately after moving to the center so that newly appeared items were not placed over old items. Importantly, to eliminate the effects of spatial factors, it was explicitly emphasized that the items appeared sequentially so that each item was hidden from an opponent (e.g., under the hide scenario) or participant (e.g., under the seek scenario) after its presentation. The total length of each sequence was 3,450 ms, including the last item fading out. Following the presentation of the four items, each participant chose the temporal position of the critical item by pressing one of four numeric keys (1–4) with no time constraints.

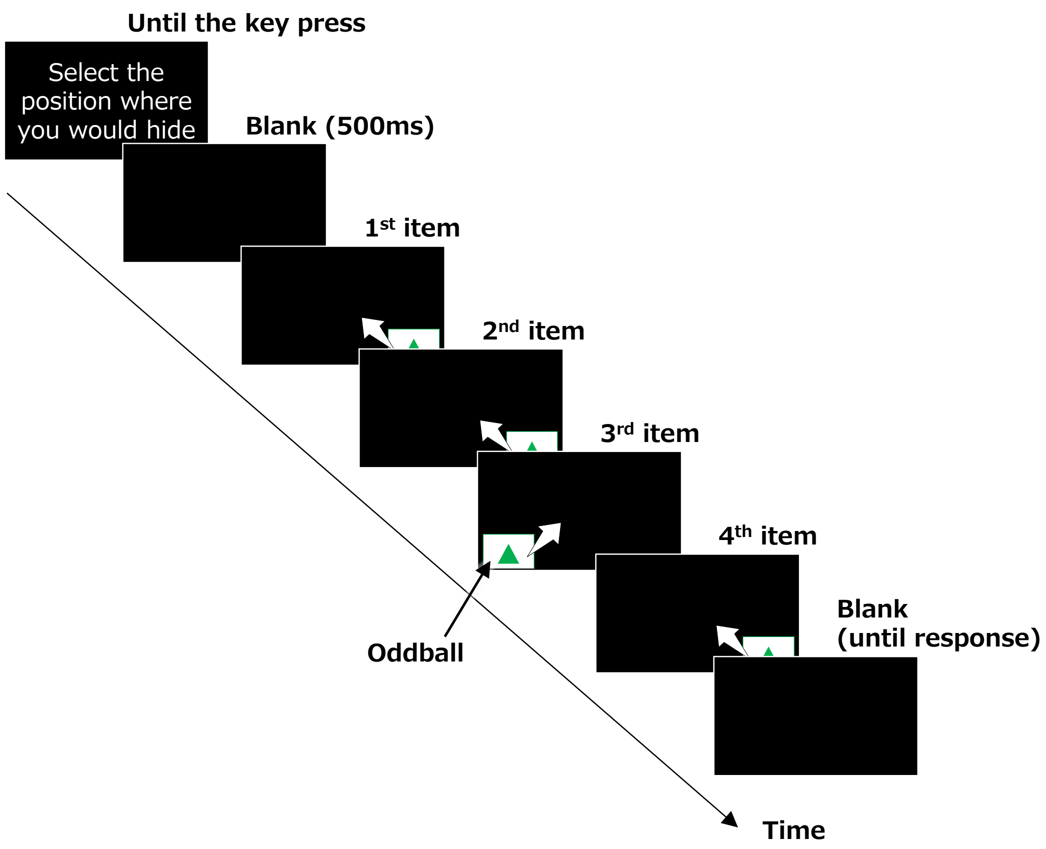

Figure 15. Semantic example of a single trial in the revised hide-find paradigm within the temporal domain (Experiment 5). All items in the sequence moved from the bottom left or right of the screen to the center of the screen when no oddball was present. When an oddball was present, one of the sequence items moved from the bottom right (or left) of the screen to the center of the screen while the remaining items moved from the bottom left (or right) to the center. Unlike the procedures in Chapter 2, each item in the present study was faded out 450 ms after visual exposure. Following the presentation of the sequence, participants guessed and reported the temporal location of the critical target across partner type (friend or foe) by pressing a corresponding key with no time constraints.

Results

Oddball-absent condition. The frequencies of item selections in each temporal position for each scenario (hide or seek) and partner type (friend or foe) when the oddball was absent were compared in Experiment 5. Pearson's Chi-squared analyses were conducted for each condition of task scenario and partner type to determine whether the temporal positions of the selected items were biased; these Chi-squared tests were also used in all following analyses in the present study. Figure 16 displays the mean frequencies of selecting one of the four possible temporal positions for each partner type and task scenario. The results revealed that the participants' selections were significantly biased by temporal position when hiding for a friend (Figure 16a, top left; χ^2 (3, N = 480) = 113.80, p < .001, w = 0.49). More specifically, multiple comparisons with binomial tests revealed that the fourth item was the most frequently selected of the temporal locations (ps < .001) (the p-values included in all of the following analyses were adjusted on the basis of the study from Benjamini & Hochberg, 1995) and that the first item was more frequently selected than the second and third items (ps < .001). The selection frequencies of the second and third items did not significantly differ (p = .07).

Next, a similar Chi-squared test was applied to assess the frequencies of selections when hiding for a foe and revealed a significant effect of temporal position (Figure 16b, top right; χ^2 (3, N = 480) = 48.18, p < .001, w = 0.32). Under this condition, the first item was the most frequently selected of the temporal locations (ps $< .03$) and the last item was more frequently selected than the second and third items (ps $< .02$). The selection frequencies of the second and third items did not significantly differ ($p = .17$).

When seeking from a friend, Chi-squared tests revealed a significant effect of temporal position (Figure 16c, bottom left; χ^2 (3, N = 480) = 231.70, $p < .001$, w = 0.69) that followed a pattern similar to the results obtained when hiding for a friend. Specifically, the fourth item was the most frequently selected of the temporal locations (ps $< .001$) and the first item was more frequently selected than the second and third items (ps $< .001$). The selection frequencies of the second and third items did not significantly differ ($p = .14$).

Finally, when seeking from a foe, Chi-squared tests revealed a significant effect of temporal position (Figure 16d, bottom right; χ^2 (3, N = 480) = 69.55, $p < .01$, w = 0.38). Specifically, the first item was the most frequently selected of the temporal positions (ps $< .004$) and the last item was the least frequently selected of the temporal positions (ps $< .001$). The selection frequencies of the second and third items did not significantly differ ($p = .08$).

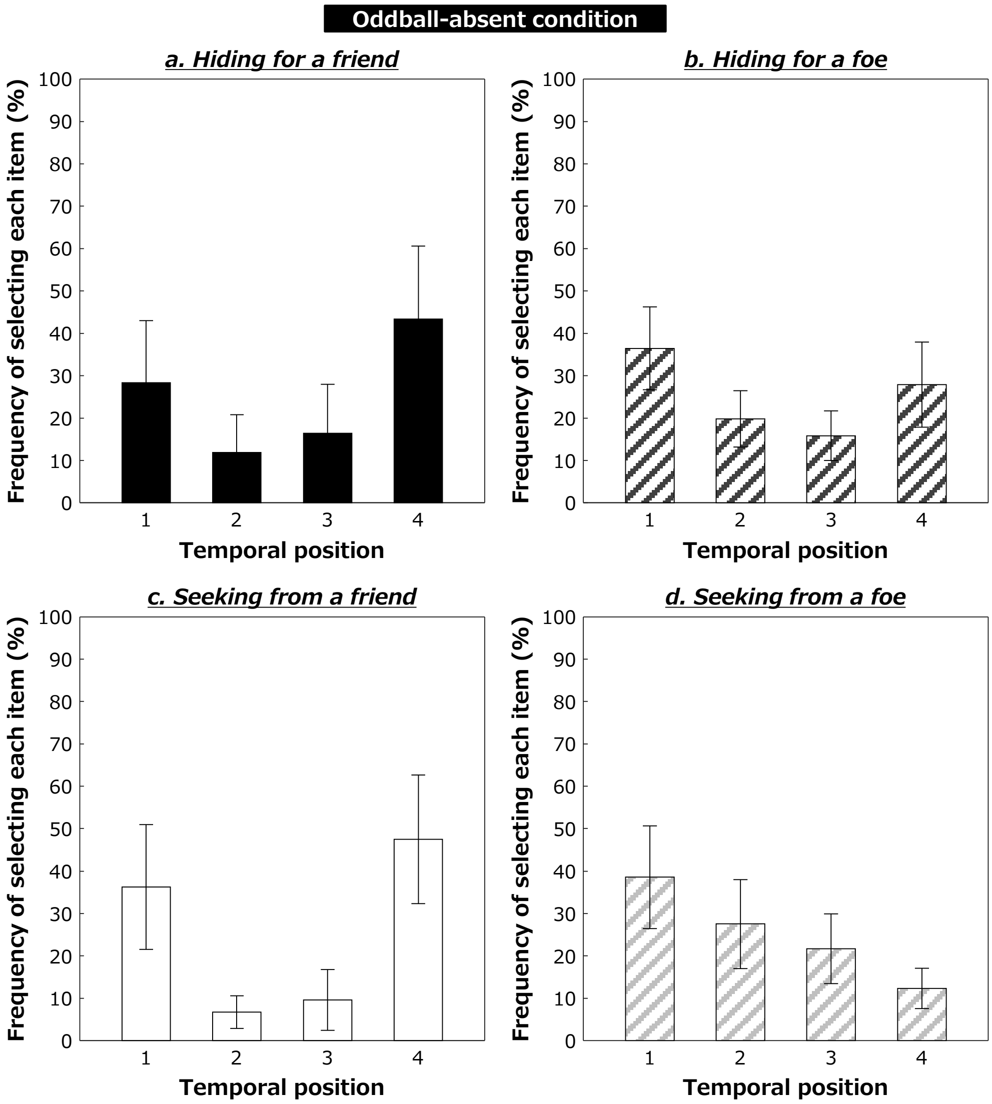

Figure 16. Frequencies of selecting the items in each temporal position under the oddball-absent condition across task scenario (hide or seek) and partner type (friend or foe) in Experiment 5. Error bars show 95% confidence intervals.

Oddball-present condition. Figure 17 shows the mean frequencies of selecting the oddball in each temporal position for task scenario (hide or seek) and partner type (friend or foe). To determine whether the selections of the oddball were biased, the frequencies of selecting the oddball under the task scenario were compared across partner type with a two-way ANOVA that included scenario as a between-subjects factor and partner type as a within-subject factor. There was a main effect of partner type (F (1, 38) = 189.03, p < .001, η_p^2 = .83), which indicates that the participants more frequently selected the oddball under the friend context than under the foe context. Although no main effect of scenario was observed (F (1, 38) = 2.76, p = .11, η_p^2 = .07), there was a significant interaction between task scenario and partner type (F (1, 38) = 5.16, p = .03, η_p^2 = .12). The simple main effect of scenario under the friend context was significant (F (1, 38) = 7.47, p = .01, η_p^2 = .16), which indicates that the frequency of selecting the oddball when hiding was higher than when seeking; no effect of scenario was observed under the foe context (F (1, 38) = 0.54, p = .47, η_p^2 = .01). The simple main effect of partner type was significant under both scenarios, which indicates that the frequency of selecting the oddball under the friend context was higher than under the foe context when the participants engaged in the hide and seek tasks (hide scenario: F (1, 38) = 65.87, p < .001, η_p^2 = .63; seek scenario: F (1, 38) = 128.33, p < .001, η_p^2 = .77).

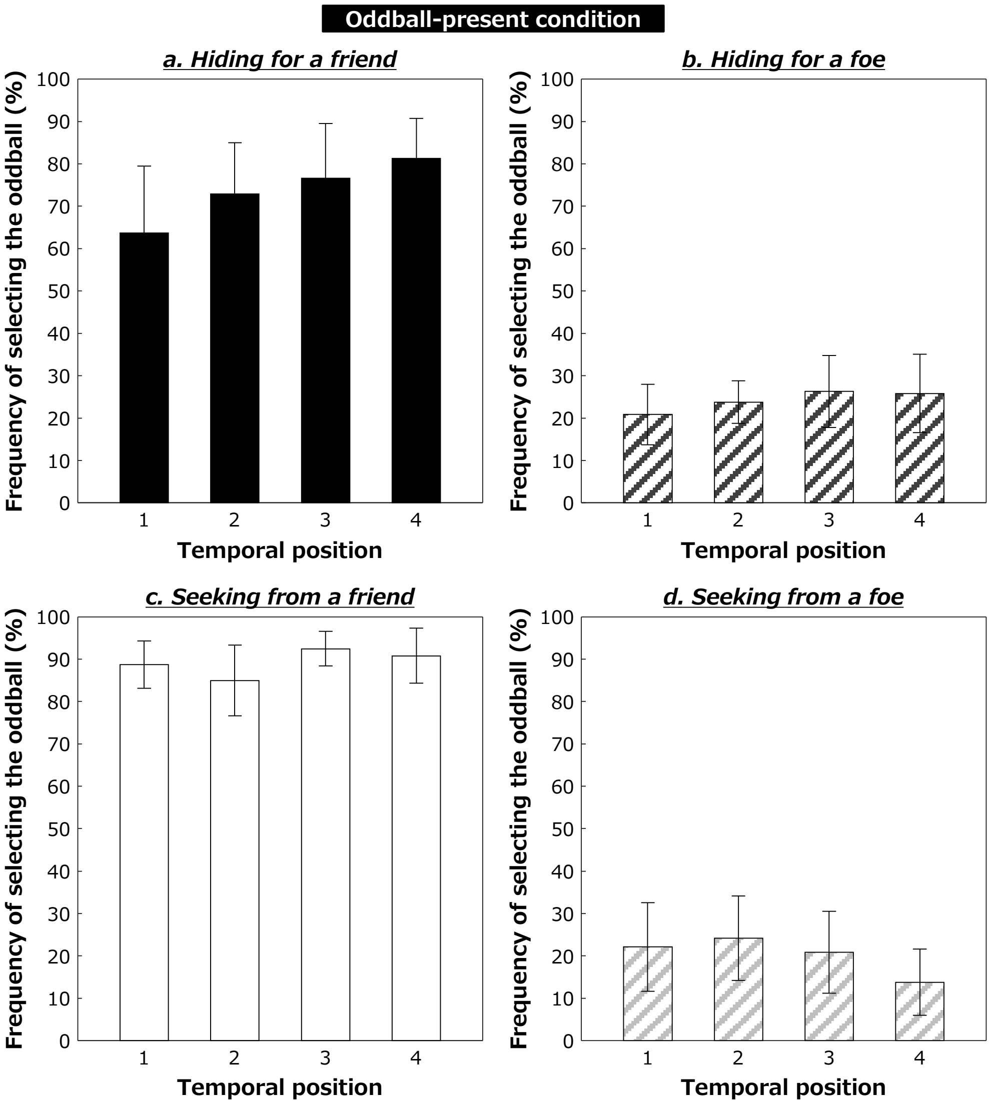

Figure 17. Mean frequencies of selecting the oddball in each temporal position across task scenario (hide or seek) and partner type (friend or foe) in Experiment 5. Error bars show 95% confidence intervals.

Discussion

Under the oddball-absent condition in both task scenarios, participants most frequently selected the fourth item for a friend and more frequently selected the first item for a friend compared to the middle (i.e., second and third) items in the temporal sequence. This pattern of the results differed from results obtained in studies of the spatiotemporal domain (Chapter 2) showing that the topmost item of stacked stimuli was by far most frequently selected for a friend. Taken together, the present results indicate that the selection biases for the first and fourth items were specific to the temporal domain and that the primacy and recency effects of short-term memory (Grenfell-Essam & Ward, 2012; Murdock Jr, 1962) might have been involved in the formation of these biases. If these serial presentation effects had been applied under the foe context, then the participants would have selected the second and third items. However, the participants more frequently selected the first item compared to the other possible items under the foe context, regardless of whether the task scenario involved seeking or hiding. This trend for selections is consistent with predictions based on the temporal remoteness hypothesis, which states that participants believe that earlier items are less salient than later items in a sequence. Thus, the selection biases observed in Experiment 5 significantly differed across partner type because participants' choices for a friend were based on serial presentation effects whereas their choices for a foe were based on temporal remoteness.

It is also possible that the selection biases observed in the non-oddball condition (i.e., participants most frequently selected the fourth item for a friend and avoided selecting later items for a foe) were related to the continuous conceptual processing of the last item. In other words, although the last item in the temporal sequence faded out, it may have been more impactful than the other items that immediately appeared. For example, the presentation of a new item blocks the recognition of a previous item when participants are asked to memorize meaningful items in a short-term memory task (conceptual masking; Intraub, 1984; Potter, 1976; Potter & Levy, 1969). It has also been reported that the conceptual masking induced by a subsequent item occurs for at least 1 second after the presentation of that item (Potter, 1976; Potter & Levy, 1969). In the present experiment, each item appeared sequentially every 750 ms and the participants were required to memorize meaningful information about the order as well as the direction the items moved in. The present findings indicate that the sequential items were susceptible to conceptual masking whereas the last item, which was not followed by subsequent items, was not affected by masking. Moreover, short-term memory studies have suggested that the saliency of a last item is reduced by the introduction of task-irrelevant items, such as a visual mask after the presentation of the last item (i.e., the suffix effect; Hu et al., 2014; Morton et al., 1971; Parmentier et al., 2004). Thus, Experiment 6 examined whether the results obtained in Experiment 5 would be replicated when the saliency of the last item was reduced by the introduction of a visual mask at the end of the temporal sequence.

It is also necessary to discuss the effects of an oddball on selection patterns. In Experiment 5, participants more frequently selected the oddball than the non-oddballs for a friend whereas they avoided selecting the oddball for a foe when engaged in both the hide and seek tasks. These results were consistent with previous search and concealment studies in the spatial (Anderson et al., 2014; Street et al., 2018) and spatiotemporal (Chapter 2) domains and, thus, can be interpreted based on the fundamental principles of those domains because the patterns of search and concealment behaviors in purely spatial and spatiotemporal domains can be extended to the purely temporal domain. Thus, it is possible that the participants believed that the oddball would attract attention and be readily discovered by a friend. In all other experiments in the present study, the effects of the oddball on selection behaviors were consistent with the results of the oddball-present condition in Experiment 5, regardless of context and scenario. Thus, extensive discussions of the results from oddball-present conditions in the following experiments were avoided.

3.3. Experiment 6

Experiment 6 examined whether the selection bias for the last item in the oddball-absent condition that was observed in Experiment 5 would be replicated when the saliency of the last item was reduced by visual backward masking (i.e., the suffix effect; Hu et al., 2014; Morton et al., 1971; Parmentier et al., 2004). The experimental procedure of Experiment 6 was similar to that of Experiment 5 except that visual backward masking was applied to the last item of the temporal sequence as it was faded out of the screen. If a reduction in the saliency of the item or the suffix effect influenced the selection process, then the selection frequency of the last item would decrease under the friend context whereas it would increase under the foe context.

Method

Participants. A new group of 40 undergraduate and graduate students (18 females, between 18 and 24 years of age) from the participant pool at Hokkaido University participated for pay or in exchange for course credit. Half of the participants (nine females, mean age = 20.05 years) were randomly assigned to the hide scenario, and the remaining half (nine females, mean age = 20.55 years) was randomly assigned to the seek scenario.

Apparatus, Stimuli, Design, and Procedure. The apparatus, stimuli, design, and procedure of Experiment 6 were the same as those used in Experiment 5. However, a visual random-dot mask that was the same size as the items in the sequence appeared for 100 ms in the center of the screen after the last item faded out; there was no inter-stimulus interval (Figure 18). We also recorded decision time from the offset of the visual mask to the completion of selection response although we did not instruct participants to respond as quickly as possible.

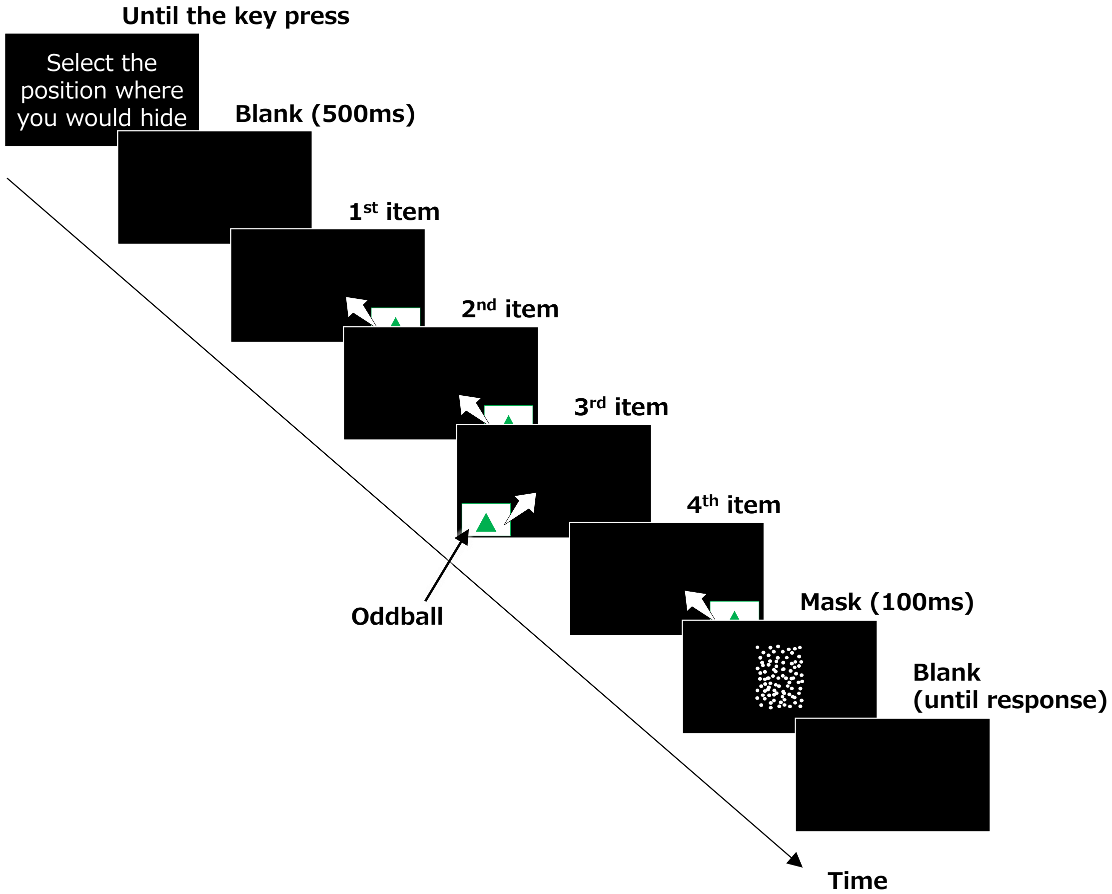

Figure 18. Semantic example of a single trial in the revised hide-find paradigm within the temporal domain (Experiment 6). All items in the sequence moved from the bottom left or right of the screen to the center of the screen when no oddball was present. When an oddball was present, one of the sequence items moved from the bottom right (or left) of the screen to the center of the screen while the remaining items moved from the bottom left (or right) to the center. Unlike the procedures in Chapter 2, each item in the present study was faded out 450 ms after visual exposure. In Experiment 6, a random-dot visual mask appeared at the center of the screen for 100 ms after the presentation of the sequence. Following the presentation of the visual mask, participants guessed and reported the temporal location of the critical target across partner type (friend or foe) by pressing a corresponding key with no time constraints.

Results

Oddball-absent Condition. The frequencies of item selections in each temporal position for each scenario (hide or seek) and partner type (friend or foe) when the oddball was absent were compared in Experiment 6. Pearson's Chi-squared analyses were conducted for each condition of task scenario and partner type to determine whether the temporal positions of the selected items were biased. Figure 19 displays the mean frequencies of selecting one of the four possible temporal positions for each partner type and scenario. Pearson's Chi-squared tests indicated that the participants' selections were significantly biased by temporal position when hiding for a friend (Figure 19a, top left; χ^2 (3, N = 480) = 140.70, $p < .001$, $w = 0.54$). More specifically, multiple comparisons with binomial tests revealed that the fourth item was the most frequently selected of the temporal locations (ps < .001) and that the second item was the least frequently selected (ps < .001). The selection frequencies of the first and third items did not significantly differ ($p = .12$).

Next, a similar Chi-squared test was applied to assess the frequencies of selections when hiding for a foe. The results revealed a significant effect of temporal position (Figure 19b, top right; χ^2 (3, N = 480) = 75.58, $p < .001$, $w = 0.40$) such that the first item was the most frequently selected of the temporal locations (ps < .001) and the last item was the least frequently selected (ps < .001). The selection frequencies of the second and third items did not significantly differ ($p = 1.00$).

Similarly, when seeking from a friend, Chi-squared tests revealed a significant effect of temporal position (Figure 19c, bottom left; χ^2 (3, N = 480) = 181.90, p < .001, w = 0.62) and that the pattern of results was similar to those obtained when hiding for a friend. More specifically, the fourth item was the most frequently selected of the temporal locations (ps < .001), the first item was more frequently selected than the second and third items (ps < .001), and the second item was more frequently selected than the third item (p = .004). In contrast, when seeking from a foe, Chi-squared tests indicated no significant effect of temporal position (Figure 19d, bottom right; χ^2 (3, N = 480) = 7.38, p = .06, w = 0.12). Likewise, multiple comparison tests indicated no significant differences among all pairs of temporal conditions (ps > .09).

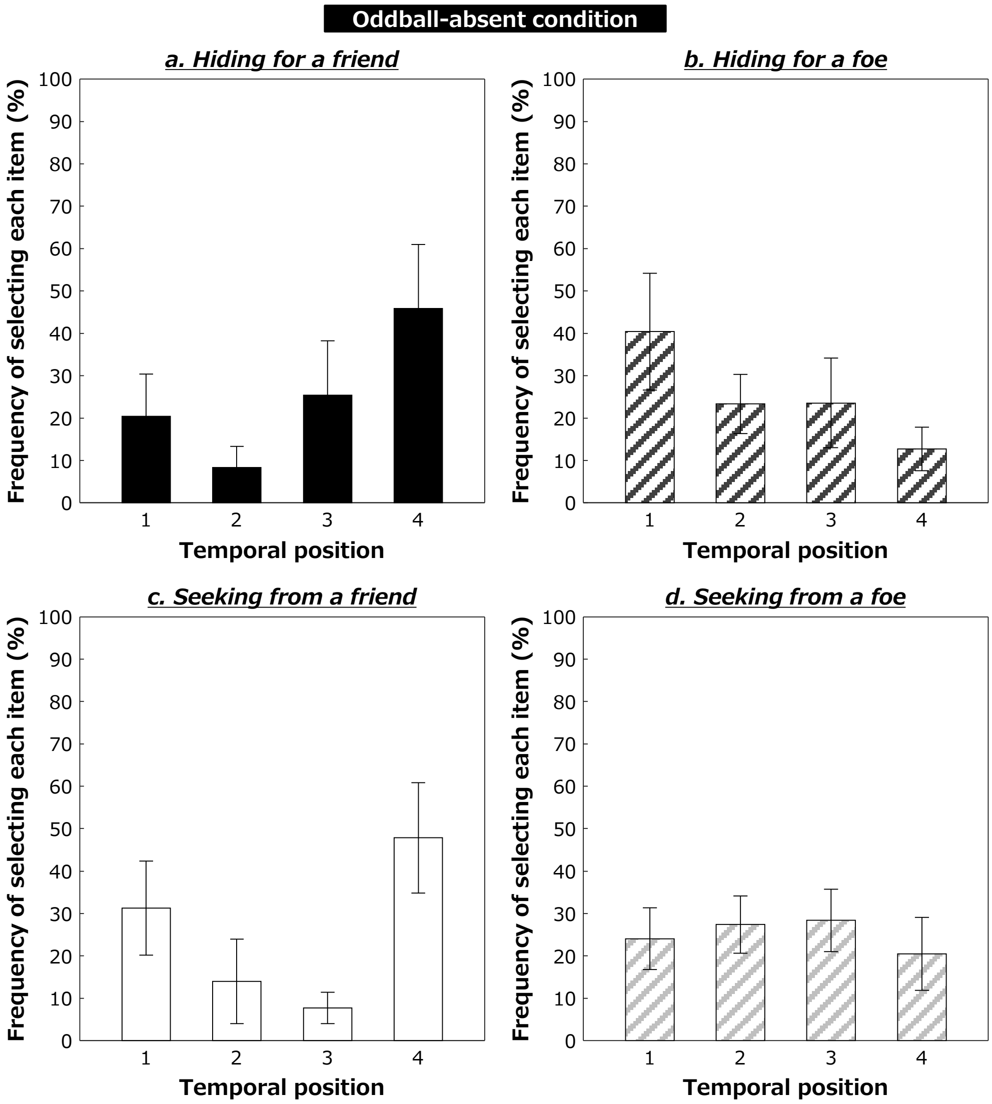

Figure 19. Frequencies of selecting the items in each temporal position under the oddball-absent condition across task scenario (hide or seek) and partner type (friend or foe) in Experiment 6. Error bars show 95% confidence intervals.

Oddball-present condition. Figure 20 shows the mean frequencies of selecting the oddball in each temporal position for task scenario (hide or seek) and partner type (friend or foe). To examine whether the selections of the oddball were biased, the frequencies of selecting the oddball under the task scenario were compared across partner type. A two-way ANOVA that included scenario as a between-subjects factor and partner type as a within-subject factor revealed a main effect of partner type (F (1, 38) = 71.90, $p < .001$, $\eta_p^2 = .65$), which indicates that the participants more frequently selected the oddball under the friend context than under the foe context. No main effect of scenario was observed (F (1, 38) = 0.59, $p = .45$, $\eta_p^2 = .02$) and there were no interaction effects between task scenario and partner type (F (1, 38) = 1.60, $p = .21$, $\eta_p^2 = .04$).

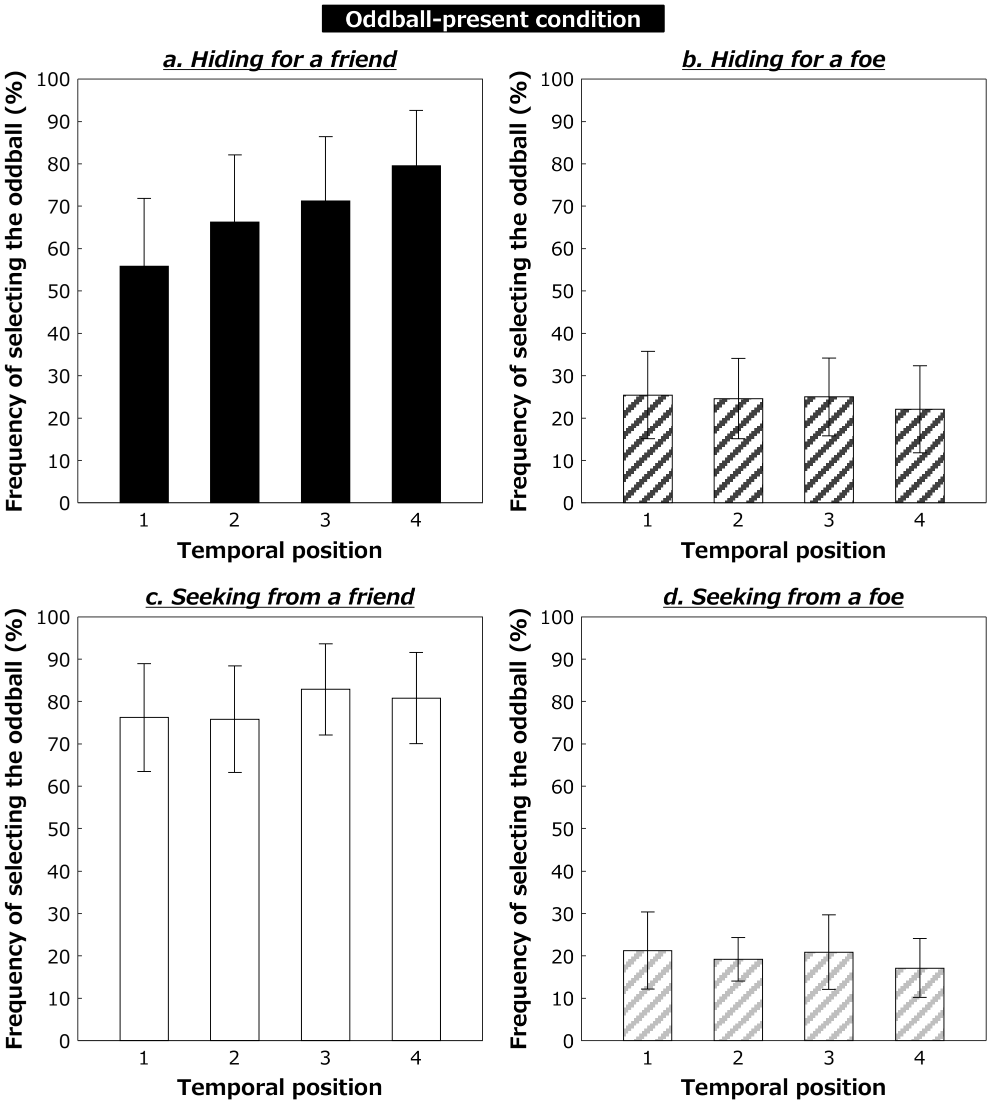

Figure 20. Mean frequencies of selecting the oddball in each temporal position across task scenario (hide or seek) and partner type (friend or foe) in Experiment 6. Error bars show 95% confidence intervals.

Completion times. In the present study, the data of 33 participants ($n_{\text{hide scenario}}$ = 16 and $n_{\text{seek scenario}}$ = 17) were analyzed because the completion times of seven participants were missing due to program failure. This study compared the time taken by participants to make a decision, which was defined as the time from the offset of the visual mask to the time when a participant selected an item, and then the median completion times in each condition were calculated; Figure 21 shows the group means of the median completion times. A three-way ANOVA that included scenario as a between-subjects factor and partner type and oddball as within-subject factors revealed no main effects of either task scenario (F (1, 31) = 0.00, p = .99, $\eta_p^2 < .01$) or oddball (F (1, 31) = 1.36, p = .25, $\eta_p^2 = .04$). However, the main effect of partner type was significant (F (1, 31) = 12.69, p = .001, $\eta_p^2 = .29$), which indicates that the completion times were shorter when selecting for friends than when selecting for foes. The interaction effect between partner type and oddball was also significant (F (1, 31) = 7.90, p = .009, $\eta_p^2 = .20$). An analysis of the simple main effect of oddball revealed that the completion times were longer under the oddball-absent condition than under the oddball-present condition when participants acknowledged that one's partner was a friend (F (1, 31) = 6.99, p = .01, $\eta_p^2 = .18$). An analysis of the simple-simple main effect of partner type revealed that the completion times were longer for foes than friends under both the oddball-absent (F (1, 31) = 6.57, p = .02, $\eta_p^2 = .17$) and oddball-present (F (1, 31) = 14.48, p < .001, $\eta_p^2 = .32$) conditions.

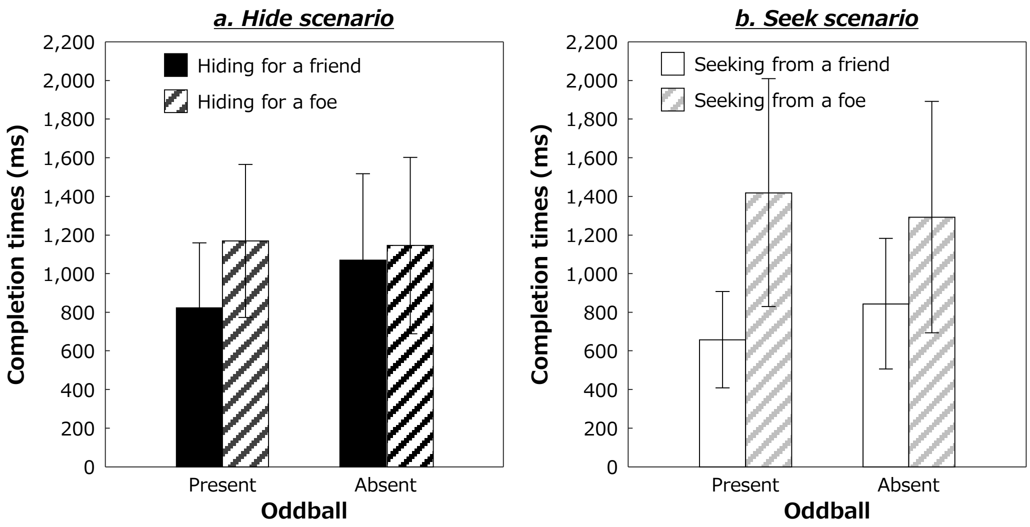

Figure 21. Means of the median completion times across task scenario (hide or seek), partner type (friend or foe), and oddball (present or absent) in Experiment 6. Error bars show 95% confidence intervals.

Discussion

Experiment 6 produced a pattern of results that was similar to those obtained in Experiment 5 under the non-oddball condition when participants engaged in both the hide and seek tasks for a friend. Specifically, participants most frequently selected the last item and also, relatively frequently, selected the first item, which indicates that primacy and recency effects influenced the selections. Although it was expected that the selection frequency of the last item would decrease due to the blocking of the conceptual processing of the last item by a backward visual mask (i.e., suffix effect), no such effect was observed in the present experiment and the results obtained in Experiment 5 were replicated.

In contrast, the pattern of results when hiding or seeking for/from a foe under the non-oddball condition substantially differed depending on task scenario. Specifically, participants most frequently selected the first item and avoided selecting the last item when hiding for a foe whereas there was no bias in selections observed when seeking from a foe. The former result was identical to selections made based on temporal remoteness while the latter result was not consistent with previous explanations. One possible explanation for this non-biased selection is the randomness of the selections (e.g., Wilke et al., 2015). Placing or picking up a target in completely random positions would appear to be a reasonable strategy because the success rates of such selections should be equal to chance regardless of the partner’s strategy. In other words, a random selection process optimizes the probability of being successful in the game. It is possible that participants would be likely to resort to relying on a random strategy if the number of options increased because a greater number of choices would lead to uniformly distributed responses for the selections (e.g., Experiment 3 in Chapter 2). Thus, in Experiment 7, the number of choices in the temporal sequence was manipulated to examine whether random selections, rather than selections made based on temporal remoteness as in Experiment 5, would be executed by the participants. Additionally, Experiment 7 evaluated whether the random selections would be specific to situations in which participants were seeking from a foe but not when hiding for a foe as in Experiment 6.

3.4. Experiment 7

Experiment 7 examined the effects of the number of options in a temporal sequence on search and concealment behaviors using two sets of predictions. First, under the oddball-absent condition, the previous results in Chapter 2 showed that an increase in the number of options leads to an equally scattered selection of the available positions for a foe. If this uniformly distributed pattern of selection responses were to occur in the present experiment, then a pattern of random selections (Wilke et al., 2015) similar to those obtained in Experiment 6 when seeking from a foe would be observed in the other three conditions (i.e., hide and seek for/from a friend and hiding for a foe). However, if temporal remoteness is critical for selections when hiding and seeking for/from a foe as in Experiment 5, then the initial items would be selected for a foe.

Secondly, the previous results in Chapter 2 also demonstrated that being presented as the last item in a temporal sequence is critical for the selection of the last item (e.g., the fourth items in the previous experiments). Thus, in Experiment 7, the primacy and recency effects would be likely to influence selection when hiding and searching for a friend such that the first and sixth (rather than fourth) items would be chosen selectively. When the temporal sequence contained an oddball, it was expected that participants would select the oddball for a friend but not for a foe due to the fundamental principles of search and concealment, which state that observers will hide (and search for) a target that attracts attention (or not).

Method

Participants. A new group of 40 undergraduate and graduate students (12 females, between 18 and 24 years of age) from the participant pool at Hokkaido University participated for pay or in exchange for course credit. Half of the participants (five females, mean age = 19.90 years) were randomly assigned to the hide scenario, and the remaining half (seven females, mean age = 19.80 years) was randomly assigned to the seek scenario.

Apparatus, Stimuli, Design, and Procedure. The apparatus, stimuli, and procedure in Experiment 7 were the same as those used in Experiment 6. However, the number of items in the temporal sequence was increased from four to six; the length of each sequence was 4,950 ms (Figure 22).

Overall, the experimental session consisted of 12 blocks 16 trials, which resulted in a total of 192 trials. In each block of 16 trials, four trials were under the oddball-absent condition and twelve trials were under the oddball-present condition. The oddball was presented twice in each of the four possible temporal locations and the order of trials was randomly determined within each block.

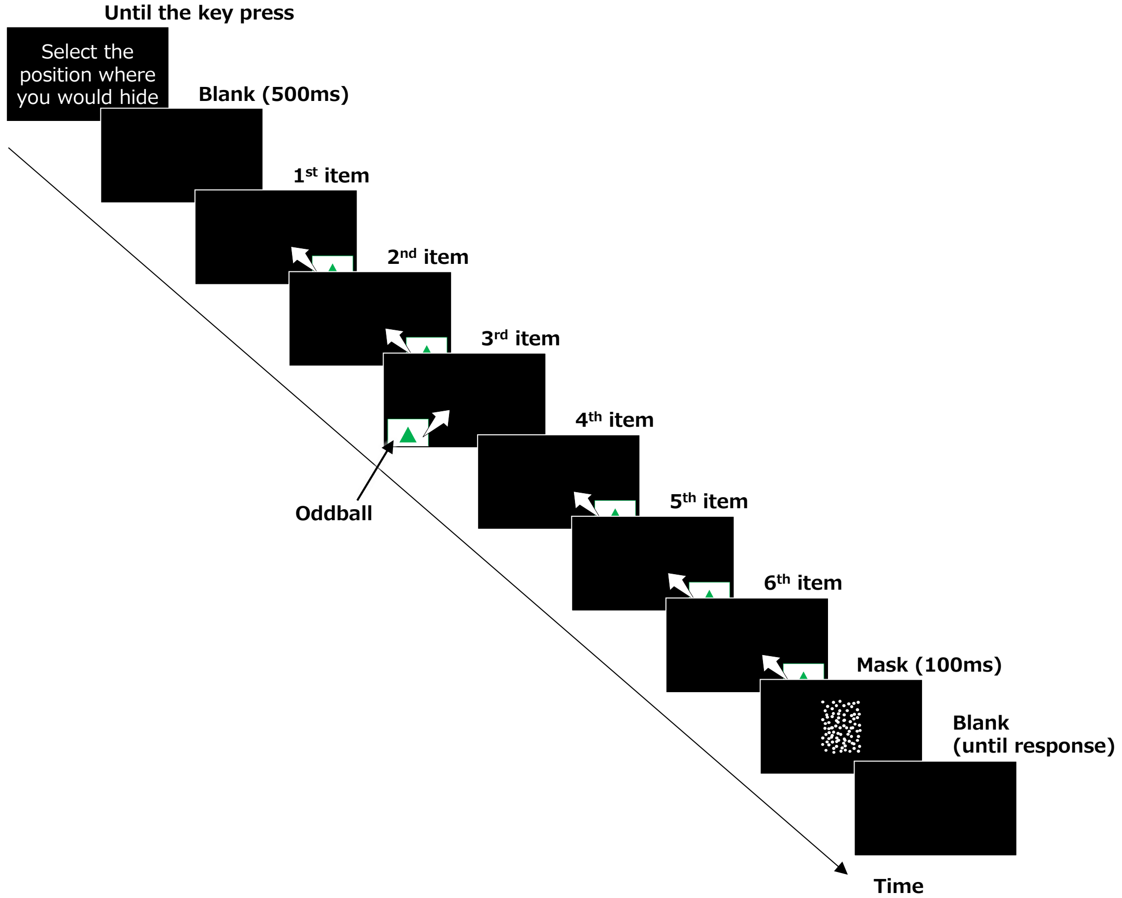

Figure 22. Semantic example of a single trial in the revised hide-find paradigm within the temporal domain (Experiment 7). All items in the sequence moved from the bottom left or right of the screen to the center of the screen when no oddball was present. When an oddball was present, one of the sequence items moved from the bottom right (or left) of the screen to the center of the screen while the remaining items moved from the bottom left (or right) to the center. Unlike the procedures in Chapter 2, each item in the present study was faded out 450 ms after visual exposure. In Experiment 7, a random-dot visual mask appeared at the center of the screen for 100 ms after the presentation of the sequence. Following the presentation of the visual mask, participants guessed and reported the temporal location of the critical target across partner type (friend or foe) by pressing a corresponding key with no time constraints.

Results

Oddball-absent condition. The frequencies of item selections in each temporal position for each scenario (hide or seek) and partner type (friend or foe) when the oddball was absent were compared in Experiment 7. Pearson's Chi-squared analyses were conducted for each condition of task scenario and partner type to determine whether the temporal positions of the selected items were biased. Figure 23 displays the mean frequencies of selecting one of the six possible temporal positions for each partner type and task scenario. Pearson's Chi-squared tests indicated that participants' selections were significantly biased by temporal position when hiding for a friend (Figure 23a, top left; χ^2 (5, N = 480) = 257.02, p < .001, w = 0.73). More specifically, multiple comparisons with binomial tests revealed that the sixth item was most frequently selected of the temporal locations (ps < .001) and that the first item was more frequently selected than the second, fourth, and fifth items (ps < .03). Additionally, the third item was more frequently selected than the second and fifth items (ps < .03) and the second item was the least frequently selected of the temporal locations (ps < .03). The selection frequencies between first and third items (p = .49) and between the third and fourth items (p = .49) did not significantly differ.

Next, a similar Chi-squared test was applied to the selection frequencies when hiding for a foe and revealed a significant effect of temporal position (Figure 23b, top right; χ^2 (5, N = 480) = 15.00, p = .01, w = 0.18). The results revealed that the sixth item was more frequently selected than the third and fifth items (*p*s $< .03$). The selection frequencies between the other pairs of temporal items did not significantly differ (*p*s $> .10$).

Similarly, when seeking from a friend, Chi-squared tests revealed a significant effect of temporal position (Figure 23c, bottom left; χ^2 (5, N = 480) = 335.83, $p < .001$, w = 0.84). More specifically, the first item was the most frequently selected of the temporal locations (*p*s $< .001$), the last item was more frequently selected than the second, third, fourth, and fifth items (*p*s $< .001$), the third item was more frequently selected than the second and fifth items (*p*s $< .001$), and the fourth item was more frequently selected than the second item ($p = .03$). The selection frequencies between second and fifth items ($p = .77$) and between the third and fourth items ($p = .14$) did not significantly differ.

Finally, when seeking from a foe, Chi-squared tests revealed a significant effect of temporal position (Figure 23d, bottom right; χ^2 (5, N = 480) = 23.95, $p < .001$, w = 0.22). More specifically, the first item was the most frequently selected of the temporal position (*p*s $< .03$) whereas the selection frequencies between the other pairs of temporal items did not significantly differ (*p*s $> .14$).

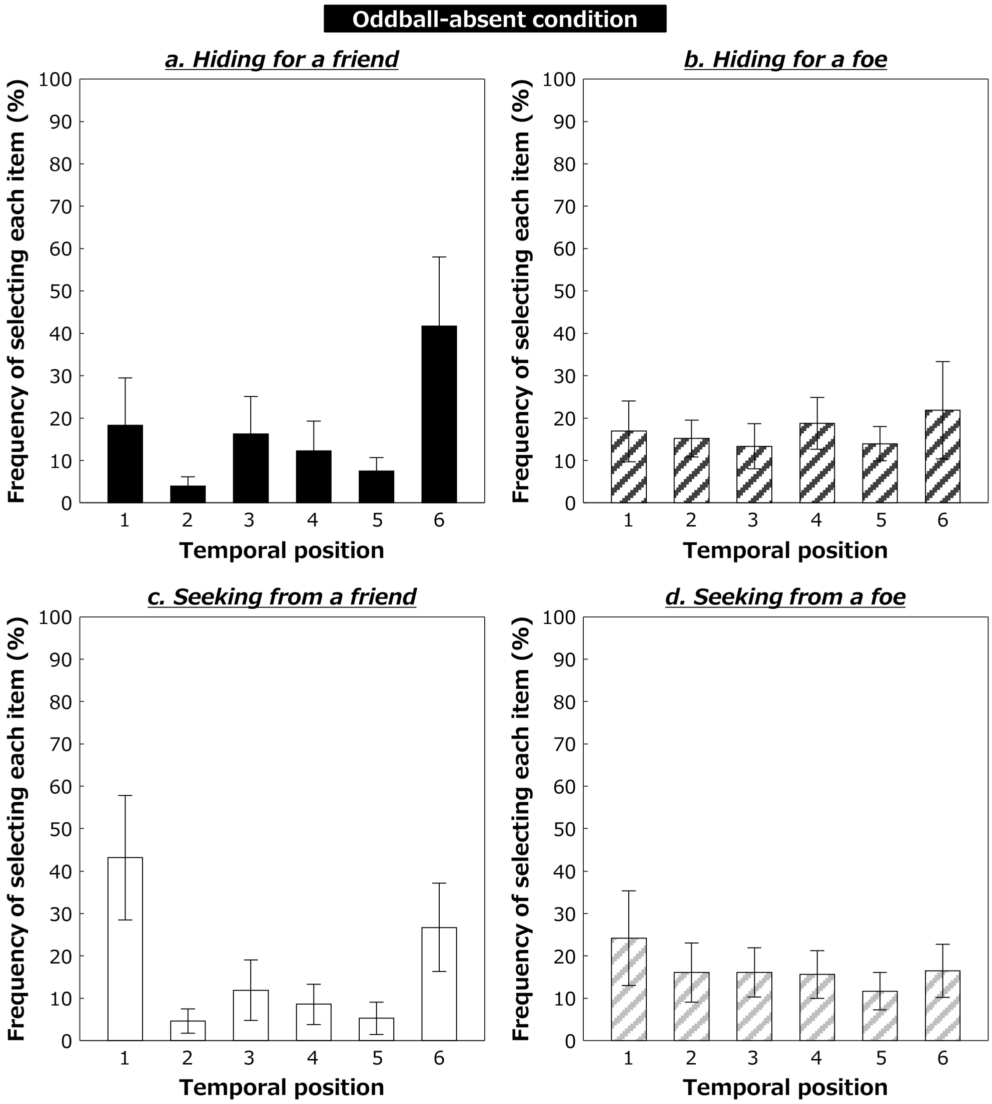

Figure 23. Frequencies of selecting the items in each temporal position under the oddball-absent condition across task scenario (hide or seek) and partner type (friend or foe) in Experiment 7. Error bars show 95% confidence intervals.

Oddball-present condition. Figure 24 shows the mean frequencies of selecting the oddball in each temporal position for task scenario (hide or seek) and partner type (friend or foe). To examine whether the selections of the oddball were biased, the frequencies of selecting the oddball under the task scenario were compared across partner type. A two-way ANOVA with scenario as a between-subjects factor and partner type as a within-subject factor revealed a main effect of partner type (F (1, 38) = 227.38, p < .001, η_p^2 = .86), which indicates that the participants more frequently selected the oddball under the friend context than under the foe context. Additionally, a main effect of scenario was revealed (F (1, 38) = 8.63, p = .006, η_p^2 = .19), which indicates that the participants were more likely to select the oddball under the seek scenario than the hide scenario. The interaction effect between task scenario and partner type was not significant (F (1, 38) = 0.01, p = .91, η_p^2 = .0003).

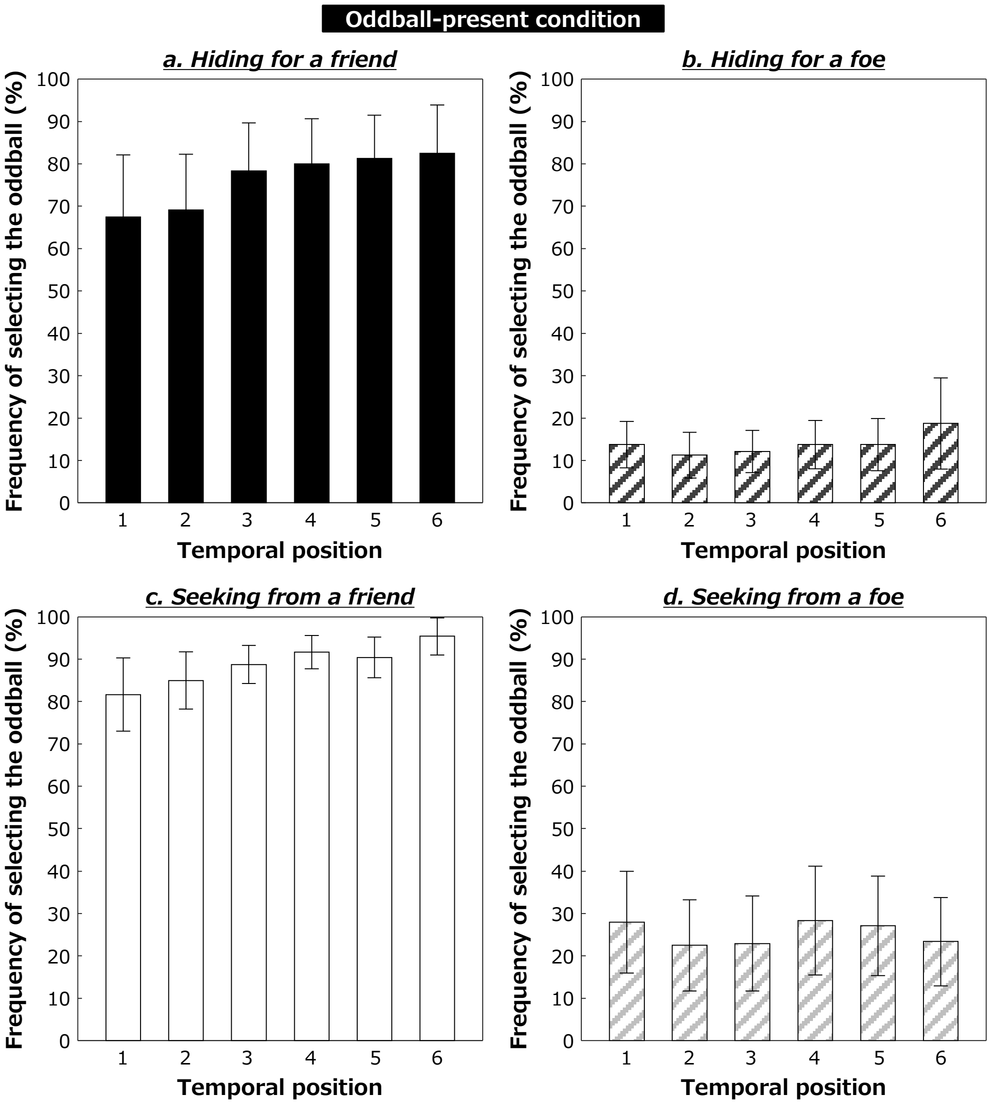

Figure 24. Mean frequencies of selecting the oddball in each temporal position across task scenario (hide or seek) and partner type (friend or foe) in Experiment 7. Error bars show 95% confidence intervals.

Completion times. The present study also compared the median completion times, which were defined as time from the offset of the mask until a participant selected an item, for each participant across the conditions; Figure 25 displays the group means of the median completion times in Experiment 7. A three-way ANOVA that included scenario as a between-subjects factor and partner type and oddball as within-subject factors revealed a significant main effect of task scenario (F (1, 38) = 6.71, p = .01, η_p^2 = .15), which indicates that the completion times were longer when hiding than when seeking. There were also main effects of oddball (F (1, 38) = 8.16, p = .007, η_p^2 = .18), which indicates that the completion times in the oddball-present condition were shorter than in the oddball-absent condition, and partner type (F (1, 38) = 15.82, p < .001, η_p^2 = .29), which indicated that the completion times were shorter during selections for friends than for foes. No interaction effects were observed in Experiment 7 (Fs (1, 38) < 1.35, ps > .25, η_p^2 < .03) in terms of completion times.

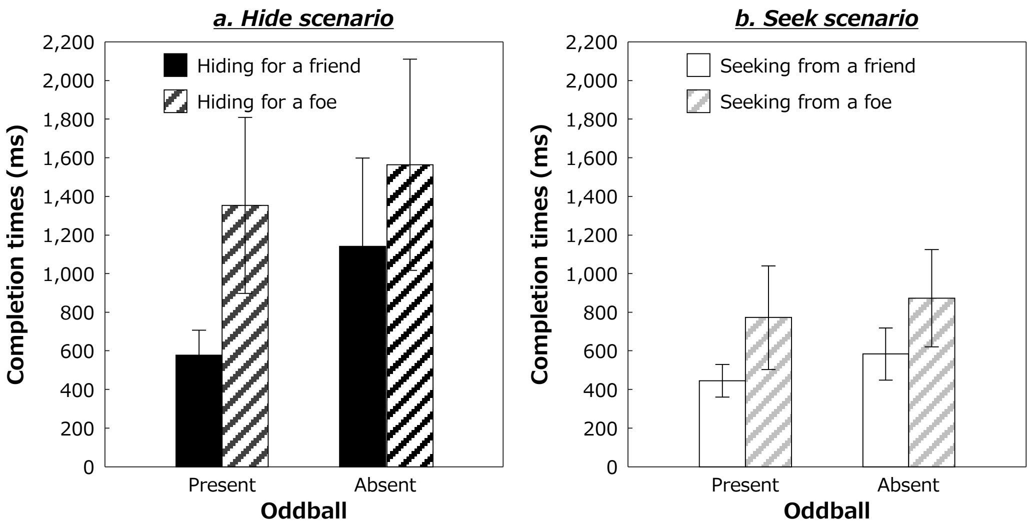

Figure 25. Means of the median completion times across task scenario (hide or seek), partner type (friend or foe), and oddball (present or absent) in Experiment 7. Error bars show 95% confidence intervals.

Discussion

When the temporal sequence did not contain an oddball, the patterns of results when hiding and finding for a friend were similar to those obtained in Experiments 5 and 6; thus, the primacy and recency effects influenced the selections. Specifically, the first and last (sixth) items were more frequently selected for a friend. However, the present results when seeking from a friend indicated that the first item was the most frequently selected of the other items, including the last item, whereas the previous experiments in this chapter showed that the last item was most frequently selected under both task scenarios. This result suggests that the primacy effect was dominant whereas the recency effect was not always critical for the present choice task in the temporal domain.

Interestingly, when the temporal sequence did not contain an oddball when hiding for a foe, the participants more frequently selected the sixth (last) item. However, this effect was weak in that the significant differences between the selection frequencies of the sixth item and the other items were only observed at the third and fifth temporal locations. Additionally, the participants most frequently selected the first item compared to the other temporal items when seeking from a foe, which is consistent with the temporal remoteness hypothesis in that the participants believed that the earlier (or later) items were not (or were) salient.

It should be noted that the two significant effects (hiding: $w = 0.18$ and seeking: *w* = 0.22) of temporal position under the foe context were weaker than those under the friend context (hiding: *w* = 0.73 and seeking: *w* = 0.84). Therefore, it is possible that the participants' selections did not rely on any dominant strategy and that they randomly made selections both when hiding and seeking for/from a foe. Taken together, the present results suggest that temporal remoteness was not always critical for selections in the temporal domain and that random selections were made by the participants.

3.5. Summary of Findings

The purpose of the present chapter was to examine search and concealment strategies in a purely temporal domain and to determine whether observers would indicate where they would find or hide a target within a temporal sequence. To this end, the hide-find paradigm was modified to investigate temporal search and concealment when items appeared sequentially in order. Unlike the abovementioned procedures in which the items appeared sequentially and were stacked, in this procedure, the items were not stacked after they appeared, and faded out after visual exposure, to eliminate the spatial factors associated with the items. When the oddball was present, the results were consistent with previous findings of studies investigating the spatial (Anderson et al., 2014) and spatiotemporal (Chapter 2) domains, as described above. In other words, observers were more likely to select salient items (the oddball) for/from a friend whereas they avoided these items for/from a foe. Additionally, as with the results obtained in Chapter 2, the present results (in Experiments 5 and 7 but not Experiment 6) revealed that the selection frequency of the oddball in the seek scenario was higher than in the hide scenario when the participants understood that their partner was a friend.

The present chapter also focused on situations in which the participants indicated where they would hide or find a target within a temporal sequence of items when the oddball was absent. In such situations, it was expected that the biases based on serial presentation (recency or primacy) effects or temporal remoteness that were observed in the previous chapter would be reflected in the selections of the participants. If biases based on serial presentation effects were applied to the temporal domain, then the first and last items would be more frequently selected for/from a friend whereas the remaining items would be more frequently selected for/from a foe. In the friend context, a bias was observed in all experiments when participants were engaged in both task scenarios whereas biases were not reflected in the selections in the foe context. In contrast, a strategy based on temporal remoteness was partially observed in the foe context. For example, participants were more likely to select the first items in Experiments 5 (both task scenarios), 6 (hide scenario), and 7 (seek scenario). In Experiment 7, although observers were more likely to select the last item when seeking from a foe, the effect of temporal position was weaker than the other effects obtained in the present study. Additionally, when observers were hiding for a foe in Experiment

6, no significant effect of temporal position was observed. Therefore, it is possible that the randomness of the selections (Wilke et al., 2015) was reflected in these results, i.e., the selections made by each observer were uniform.

The completion time data obtained in the present chapter were similar to the results obtained in the previous chapter. Specifically, there was a main effect of partner type, which indicated that the response times were shorter in trials under the friend context than in trials under the foe context. These results suggest that observers made more complex estimations in the foe context than in the friend context. Additionally, the observers estimated the target position more quickly in the friend context when the oddball was present than when the oddball was absent (Experiment 6). This result was identical to the results obtained in the previous chapter, which indicates that the selections of the oddball, especially in the friend context, were evident in the selection frequencies and were made intuitively. In Experiment 7, there were main effects of task scenario and oddball, which indicates that the observers estimated the target position more quickly when the oddball was present than when the oddball was absent, and when observers were engaged in the seek scenario than when they were engaged the hide scenario. These results were identical to those obtained in Experiment 3, which assessed hiding and seeking behaviors when there were six possible items in the sequence rather than four. Therefore, the completion times were likely to have been influenced by the task scenario and oddball conditions due to the increased number of items, even though the effect of partner type on completion times was dominant regardless of the number of the items.

CHAPTER 4. GENERAL DISCUSSIONS

4.1. Spatiotemporal Principles of Search and Concealment

Chapter 2 examined the temporal principles involved in hiding and finding using a revised hide-find paradigm (Anderson et al., 2014; Street et al., 2018). Throughout the four experiments conducted in this study, observers were more likely to select the oddball (when it was present) for friends but not for foes in both the hiding and seeking scenarios. This strategy was identical to the strategy that is employed during search and concealment in the spatial domain (Anderson et al., 2014; Street et al., 2018). In the present situations of temporal search and concealment, fundamental strategies for hiding and finding were applied such that observers selected salient items/positions more frequently for friends and non-salient items/positions for foes. In other words, based on their intuitions about the difficulties of searching and the ease of discovering a target item, the observers probably believed that the oddball would attract the attention of a supposed friend, who could be a finder or hider, but they avoided choosing the singleton for a foe.

However, the strategies for hiding and searching differed in Chapter 2. The frequencies of selecting an oddball for friends in the hide scenario were lower than those in the seek scenario. Observers applied more complex strategies when hiding than when finding because concealment behavior was applied to knowledge regarding search difficulty (Anderson et al., 2014; Smilek et al., 2009). However, when an oddball was present, observers required longer decision times for foes than for friends in both task scenarios. Taken together, these results indicate that different cognitive processes were involved in making a selection depending on partner type (i.e., social context: friend or foe). It is possible that the observers estimated the finder's allocation of attention in two steps. In the first step, they expected that the finder's attention would be captured by the oddball because the oddball was reasonably salient. This intuition should be supported by participants' impressions obtained from their viewing of the sequence and can be assigned as a metacognitive estimation of friends' searching and hiding behaviors. In the second step, the observers would estimate foes' searching and hiding behaviors based on this intuitive estimation so that the salient items would be avoided. The involvement of this second stage was reflected in the completion times as the effect of partner type (friend or foe) when the oddball was present. Thus, it is possible that when participants were mentally simulating the trajectories of another's attention during searching and hiding, the presence of an oddball made this estimation easier due to the common sense idea that the oddball should drive the initial allocation of the other's attention towards it, regardless of scenario and partner type. Therefore, the frequencies of selecting items were straightforward and consistent across the experiments when an oddball was present.

In line with the two steps of attentional allocation, the present choice behaviors seem to be related to the reflection effect (e.g., Kahneman & Tversky, 1979) in which individuals are essentially likely to be risk-averse during a risky choice, leading to gains, and to be risk-seeking during a risky choice, leading to losses, in a game such as the present task. There is an asymmetric relationship between gains and losses and, thus, it is assumed that observers switched such choice modes across partner type. In other words, observers are likely to select a particular target position conservatively and consistently in the friend context and contemplate various choices in the foe context to avoid loss. Therefore, the results of the completion times showed that longer times were required in the foe context relative to in the friend context. The idea is also identical to the high consistency of selection frequencies in the friend context and varied choices in the foe context relative to the friend context.

Importantly, the present study in Chapter 2 was primarily concerned with spatiotemporal search and concealment strategies when an oddball was absent and, thus, two specific alternative hypotheses were tested. First, if the spatial principles involved in hiding and finding, in which participants prefer edge items for friends and central items for foes, are based on natural intuitions regarding search difficulties (e.g., Anderson et al., 2014; Smilek et al., 2009) or serial order effects (primacy and recency effects) and are critical for selection strategies, then the first and last items would be selected for friends and the other items would be selected for foes. Second, if physical accessibility based on the spatial structures of the stacked items (Solman et al., 2012;

2014; Street et al., 2014), which conveys the perception of ease or difficulty when reaching for items, was critical for the pattern of the present results, then the top-layered (or bottom-layered) items would be selected for friends (or foes). The present results supported the latter hypothesis in the case of hiding and searching for the target for/from a friend. Specifically, the observers hid or found the topmost stacked items (e.g., last items in Experiments 1–3 and first item in Experiment 4) for/from a friend. These results suggest that the observers estimated the selection of a supposed friend as a hider or finder based on the spatial structure of the spatiotemporal sequence so that the ease of picking the item was affected.

In contrast, the present data do not support the physical accessibility hypothesis when hiding and seeking a target for/from a foe. In Chapter 2, observers more frequently selected the items that appeared relatively early (e.g., first and second items) in the temporal sequence when hiding and finding for/from a foe. This selection tendency occurred regardless of whether physical accessibility was represented by the stacked direction. More specifically, in Experiment 4, the items were stacked in a downward direction so that the latter items in the sequence became less accessible than the earlier items, whereas the items in Experiments 1–3 were stacked in an upward direction so that the latter items became more accessible. If the perceptual accessibility-based strategies had been observed in Experiment 4, then the last items to be placed in the bottommost positions would have been more frequently selected. Thus, it is possible that search and concealment strategies might dramatically differ depending on partner type. In other words, participants may adopt strategies based on physical accessibility when they interact with a friend whereas they may adopt strategies based on temporal remoteness for a foe.

Experiments 2 and 3 in the present study individually examined and dismissed minor factors that could have contributed to the effects of partner type and task scenario on the selection of items. In Experiment 2, the possibility that the more frequent selection of the last item for friends in the oddball-absent condition was due to perceptual visibility was excluded by demonstrating that this biased selection remained even when the last item was visually masked. That is, the present results support the physical accessibility account. In Experiment 3, the possibility that the present results were specific to the four-item sequence used in the study was excluded by increasing the number of items from four to six. The subsequent results in the present study were virtually identical to those of previous experiments, which suggests the generality of the present findings. However, in the present study, increasing the number of the items in the sequence influenced the time to make a selection because the completion times in Experiment 3 (e.g., selections from six possible items) were longer than those in the other experiments (e.g., selections from four possible items). More specifically, the completion times in the hide scenario from a foe in Experiment 3 were longer when the oddball was absent. These data are consistent with the second stage account of estimation that utilizes conscious processes that are limited in terms of capacity. In contrast, the completion times in both the hide and seek scenarios from a friend in Experiment 3 were similar to those in Experiments 2 and 4, when the oddball was present. These results support the first stage account stating that participants would estimate searching and hiding positions on the basis of unconscious processes (e.g., intuitive impressions) regardless of the number of the possible items.

The hide-find paradigm (Anderson et al., 2014; Street et al., 2018) was originally developed as a measurement tool for examining theory of mind (Baron-Cohen, Leslie, & Frith, 1985; Premack & Woodruff, 1978) in adults. However, previous studies have also used this paradigm to explore the development of search and concealment in children (Cornell & Heth, 1986; Somerville & Capuani-Shumaker, 1984; Wellman et al., 1979) as well as food hoarding and cache protection in animals (Clayton & Dickinson, 1998; Dally et al., 2004, 2005; Garamszegi & Eens, 2004; Krebs et al., 1989) by focusing on cognitive abilities such as memory and executive function. Theory of mind involves the ability to accurately assess others' beliefs, intentions, desires, and knowledge and is essential for search and concealment behaviors (Anderson et al., 2014; Street et al., 2018) because search items are usually hidden by hiders so that finders will (or will not) find it. That is, finders or hiders need to estimate the intentions of another. The accurate assessment of others' intentions leads to efficient search and concealment and vice versa. Based on the present results, it is possible to conclude that the present task engaged theory of mind because the hiding and finding positions were strategic under all circumstances (e.g., task scenarios, partner types, and presence or absence of the oddball). Furthermore, the present study revealed that these strategies can be flexibly employed based on a variety of circumstances, including partner type (friend or foe) and task scenario (hide or seek). Thus, observers can assess partners' intentions by simulating strategies that the partner would adopt or in which an opponent would attend to salient sequential positions or an oddball.

However, based on the present findings, it remains unclear how *accurately* observers can access others' intentions because the present task simply estimated hiding and finding positions without feedback regarding success (or failure) of the search and concealment. Hence, as a unique feature of the present study, the accuracy of the intentions between the task scenarios (hide or find), depending on condition (partner type or oddball) and temporal position of the oddball, was estimated by conducting the following three steps in each experiment: (1) all selection data were analyzed and randomly aligned in each experimental condition, (2) hit rates of the selected positions between the hide and seek scenarios were calculated across the same partner type and oddball conditions, and (3) steps 1 and 2 were repeated five times because this number of iterations produces a mean hit rate that never changes even if a greater number of iterations is implemented due to a small variance of the mean hit rate. The hit rate represents the accuracy rates between finders' and hiders' intentions in the friend context due to sharing the same goal whereas it represents the accuracy rates of finders' and hiders' intentions in the foe context due to the presence of different goals. For example, if the hit rate was above chance in the friend context, then the observers in each task scenario could accurately estimate mutual intentions. If the hit rate was equal to chance in the foe context, then observers in the seek scenario could not accurately estimate hiders' intentions, or, the observers in the hide scenario could accurately estimate finders' intentions.

Figure 26 displays the mean hit rates across partner type (friend or foe) and oddball (oddball-present or oddball-absent). Not surprisingly, in the oddball-present condition, the hit rates in the friend context were above chance in all experiments, which means that both finders and hiders could accurately estimate the intentions of each other. However, in the oddball-present condition, the hit rates in the foe context were equal to chance in all experiments, which means that finders could not accurately estimate hiders' intentions and that hiders successfully concealed a target. Importantly, these results were similar to the hit rates in the oddball-absent condition. In other words, both finders and hiders could accurately estimate each other's intentions when they acknowledged that the partner was a friend even if the oddball was absent. However, finders could not accurately estimate hiders' intentions, while hiders could successfully conceal a target. These results suggest that common strategies were used in the friend context whereas hiders had an advantage in the foe context. The former results were identical to the results of the selection frequencies in the present study and were likely to be due to the use of simpler (e.g., more intuitive) strategies for friends relative to foes. In contrast, the latter results might have been caused by randomness of selection. For example, a visual inspection revealed that the selections at particular temporal locations (i.e., the topmost items, such as the last items in Experiments 1–3 and the first item in Experiment 4) were dominant in the friend context whereas there were no such trends observed in the foe context. Interestingly, the selections were actually strategic for hiders because placing a target in random positions without regularity leads to increased difficulty when searching (e.g., Wilke et al., 2015). The present findings may introduce new opportunities for examining theory of mind by comparing hit rates between selected positions in the contexts of search and concealment.

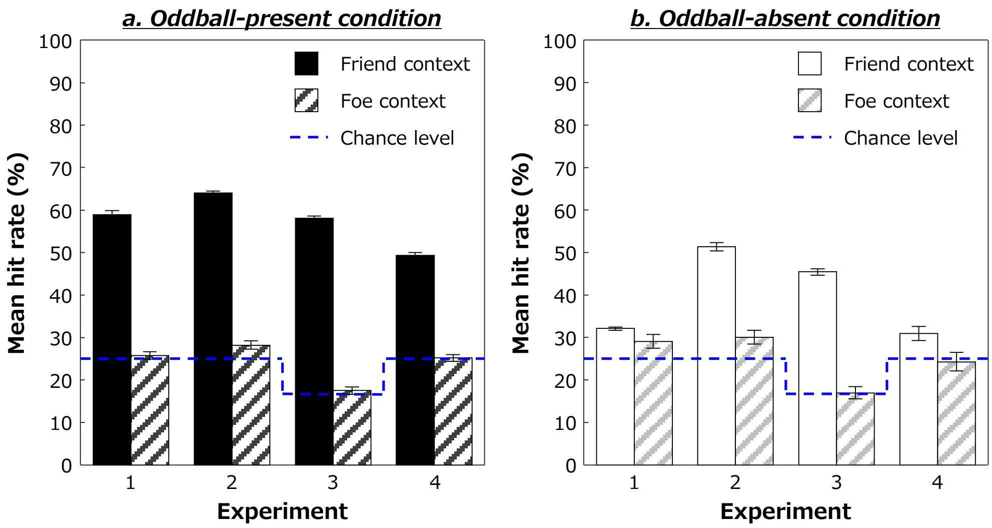

Figure 26. Mean hit rates between the selected items for task scenario (hide and seek) across partner type (friend and foe), oddball (present and absent) in Experiments 1–4. Under the oddball-present condition, the results were collapsed with the temporal position. Error bars show one standard deviation and dashed lines show chance levels (25.0% in Experiments 1, 2, and 4; 16.7% in Experiment 3). If the partner type was friend, then there was a higher chance that both the hide and seek groups would accurately select the temporal position. If the partner type was foe, then there was a higher chance that the hide group would fail the selection whereas the seek group would succeed.

4.2. Temporal Principles of Search and Concealment

Chapter 3 examined the principles of search and concealment using a hide-find paradigm in the purely temporal domain to expand on knowledge obtained from previous studies that focused on the spatial domain (e.g., stacks of items in Chapter 2, or spatially distributed items: Anderson et al., 2014; Street et al., 2018). To this end, the present study employed a situation in which observers search for or hide a target item in an oddball-absent condition and assessed two alternative hypotheses regarding the selections of the participants. First, it was hypothesized that the observers would select a target according to biases based on serial presentation effects (i.e., recency and primacy effects; Grenfell-Essam & Ward, 2012; Murdock Jr, 1962). If these biases were reflected in the selections, then the observers would more frequently select the first and last items in the friend context and more frequently select the remaining intermediate positions in the foe context. Secondly, it was hypothesized that the observers would select a target based on temporal remoteness, which would reflect the metacognition that earlier items are not salient, as with the results in Chapter 2. Accordingly, observers would select later items in the friend context whereas they would select earlier items in the foe context. Taken together, the present results indicated that the search and concealment strategies used by the participants differed dramatically depending on partner type, which is consistent with the findings in Chapter 2. However, a principle unique to the temporal domain emerged in Chapter 3.

Specifically, the first and last items were more frequently selected when observers engaged in both the hiding and seeking tasks in the friend context. These results indicate that the biases associated with the recency and primacy effects influenced selections in the friend context such that the observers estimated that these items would be more salient than the other items for a friend who could be a finder or hider.

On the other hand, in the foe context, selections appeared to be based on temporal remoteness, at least in part. More specifically, observers chose the first item for a foe in Experiment 5 (both task scenarios), Experiment 6 (only hide scenario), and Experiment 7 (only seek scenario), which indicates that the observers estimated that the first item would not be salient. However, no such trend was observed in Experiment 6 (seek scenario) and Experiment 7 (hide scenario). Accordingly, the former results showed no significant effects of temporal position (effect size: $w = 0.12$) in the first place whereas the latter results showed a smaller effect of temporal position ($w = 0.18$) than in the other experiments in Chapter 3 (ws > 0.32 in the same conditions) and no bias of temporal remoteness. Taken together, these findings indicate that the observers were more likely to select the last item than any of the other items. In contrast to the present results in Chapter 3, previous hide-find paradigms could determine the relatively high-powered effects of the spatial (e.g., $\eta_p^2 > .25$; Anderson et al., 2014) and temporal positions (mean (*SD*) of w values[2] = 0.63 (0.38) in Chapter 2) throughout all experiments, even when the oddball was absent.

There are two plausible explanations for the results of the present temporal search and concealment experiments. First, the temporal search and concealment procedure used in Chapter 3 may have been insufficiently sensitive to detect observers' estimations, at least when observers engaged in tasks in the foe context. In other words, the strategies that participants applied to their selections might have differed within and/or across individuals. Secondly, it is possible that the non-biased selections observed in the present study were due to the adoption of a fixed strategy based on the randomness of selections (e.g., Wilke et al., 2015), which posits that observers would select completely random positions for a target. These types of selections are useful when an observer's strategy is not determined because the success of the selections would be equal to chance (at least) and failure would be minimized regardless of the partner's strategy. Taken together, the present results suggest that the role of temporal remoteness was minimal for selections made in the temporal domain and that the general effects of temporal positions would be likely to disappear due to the use of a random strategy (e.g., uniformly distributed selections).

Thus, to examine whether a random strategy could be used to select target locations efficiently, the hit rates of the different task scenarios were analyzed using the method described in the previous section (Section 4.1). I calculated the probability of how accurately observers (hiders and finders) could access a partner's intentions when guessing the target locations in the absence of feedback (i.e., regarding the success or failure of search and concealment). Additionally, the accuracy rates of intentions were compared between task scenarios (i.e., hiding and finding) across partner type and the presence or absence of the oddball.[3] In the friend context, the hit rate represents the accuracy between the hiders' and finders' intentions because hiders and finders share the same goal, i.e., both are attempting to achieve higher hit rates. Thus, hit rates that are above chance level in the friend context indicate that the observer could accurately estimate mutual intentions. In contrast, in the foe context, the hit rate represents the accuracy of hiders' and finders' intentions because hiders and finders have different goals, i.e., hiders (or finders) are attempting to achieve lower (or higher) hit rates. Thus, hit rates that are below or equal to chance level in the foe context indicate that finders could not accurately estimate hiders' intentions or that hiders could accurately estimate finders' intentions.

Figure 27 shows the mean hit rates across partner type (friend or foe) and oddball (oddball-present or oddball-absent) in each experiment. In the foe context, the mean hit rates were exactly equal to chance when the sequence of items did not contain an oddball; this trend was dominant in Experiments 6 and 7 in which observers might have selected targets based on a random strategy. Thus, it is possible that placing/picking up a target in/from random positions does not lead to a significant degree of success in the task but, rather, optimizes the probability that one might be successful. In the friend context, the present results indicated that observers could accomplish the same goal for finders and hiders by using common strategies regardless of the oddball condition. This pattern of results is consistent with the patterns of search and concealment in the spatiotemporal domain (Chapter 2). Overall, the analyses of hit rates and selection frequencies revealed that observers' strategies were more complicated in the foe context than in the friend context.

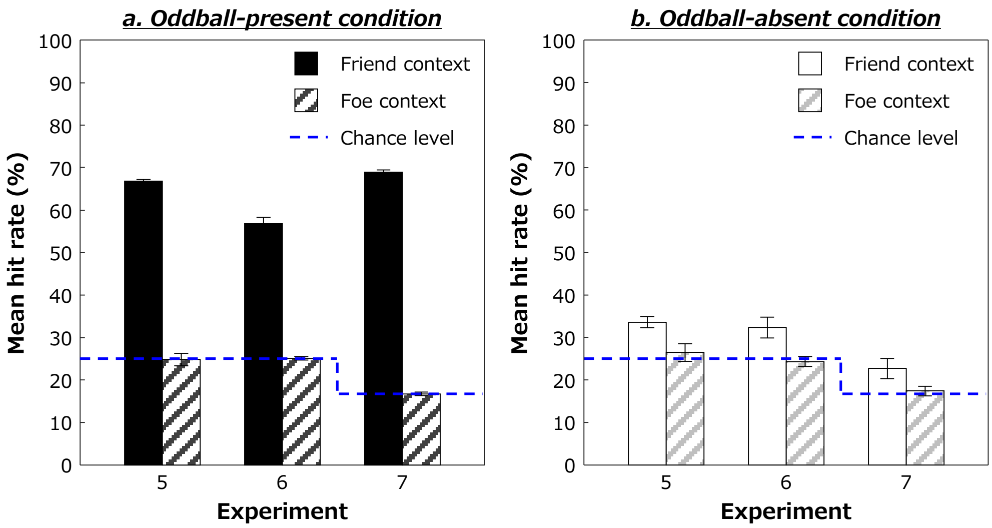

Figure 27. Mean hit rates between the selected items for task scenario (hide and seek) across partner type (friend and foe), oddball (present and absent) in Experiments 5–7. Under the oddball-present condition, the results were collapsed with the temporal position. Error bars show one standard deviation and dashed lines show chance levels (25.0% in Experiments 5 and 6; 16.7% in Experiment 7). A higher chance level in the friend context indicates that observers accurately selected the temporal position in both the hide and seek conditions. However, a higher chance level in the friend context indicates that observers would fail in their selection when hiding whereas they would succeed when seeking.

Chapter 3 also independently examined and dismissed factors that could have contributed in some way to the effects of partner type and task scenario on target selection in Experiments 6 and 7. For example, because the last item might be more salient than the other items, Experiment 6 (and Experiment 7) ruled out the possibility that more (or less) frequent selections of the last item for a friend (or foe) were related to the continuous conceptual processing of the last item by presenting a conceptual mask after exposure to the last item. The present results indicated that the bias for a more frequent selection of the last item for a friend remained even when the last item was masked. In other words, the primacy and recency effects influenced the selections. It should be noted that the participants either adopted a random strategy or made more frequent selections of the last item (e.g., hide scenario in Experiment 7) when presented with the mask in Experiments 6 and 7; no such strategy was observed in Experiment 5. Thus, the present results suggest that this experimental manipulation in the hide-find paradigm might be critical for target selection and, therefore, future studies should explicitly determine the role of masking on selections. Finally, to determine whether being the last item rather than merely the fourth item was critical, Experiment 7 increased the number of items in the temporal sequence from four to six and revealed that biases based on the recency and primacy effects influenced the selections.

Under the oddball-present condition, observers were more likely to select the oddball for friends than for foes in both the hiding and seeking scenarios. This result was identical to previous findings of search and concealment behaviors in the spatial (Anderson et al., 2014; Street et al., 2018) and spatiotemporal (Chapter 2) domains. That is, the fundamental strategies of hiding and finding in which observers more frequently select salient items/positions for a friend and non-salient items/positions for a foe also applied to the present task in the temporal domain. Therefore, it is possible that the observers selected a target based on their metacognition regarding the ease or difficulty of discovering an item. More specifically, observers estimated that the oddball would attract the attention of their partner (i.e., friend), who could be a hider or finder, but avoided choosing the oddball for a foe because they predicted that it would capture the foe's attention and, thus, it would be better to disregard the oddball. Based on the hit rate analyses, it was evident that a common strategy (e.g., more than 50.0% of the hit rates were beyond the chance level in the friend context) was consistently adopted by the hiders and finders.

4.3. Limitations and Future Directions

Although the present study focused on search and concealment behaviors that are related to daily life, the present hide-find paradigm cannot directly explain related strategies that might occur in the real world because the actual situations and interpersonal interactions between hiders and finders are more complicated than the manipulations employed in the present task. For example, a variety of potential factors can influence search and concealment strategies or decision-making, including feedback or learning (Lim, O’Connor, & Remus, 2005; Pachur & Olsson, 2012), status, attributes, the relationship between observers and the opponent (Bach, Pham, Schrag, Tate, & Hargraves, 2004; Cooper-Patrick et al., 1999), aging (Eppinger, Walter, Heekeren, & Li, 2013; Mata, von Helversen, & Rieskamp, 2010; Mata, Josef, Samanez-Larkin, & Hertwig, 2011), motivation (Richter & Tjosvold, 1980; Worthy, Maddox, & Markman, 2007), and personality (Lev, Hershkovitz, & Yechiam, 2008).

In the present and previous studies of search and concealment behavior, participants were required to guess the search and concealment positions but did not receive feedback (e.g., success or failure) regarding their selections (e.g., Anderson et al., 2014; Street et al., 2018). However, selections and/or strategies are likely to be always modified by such feedback, which would induce participants to choose reasonable strategies and improve their precision in terms of search and concealment. Thus, it is possible that the hit rate analyses described in the present study (Sections 4.1 and 4.2) would contribute to an understanding of the effects of feedback on target selection.

This type of learning through feedback is also susceptible to aging (Eppinger et al., 2013; Mata et al., 2010; Mata et al., 2011). For example, younger participants are more efficient than older participants at learning, due to the effects of age-related cognitive decline (Craik & Rose, 2012). On the other hand, elderly participants have acquired metacognitive behaviors (Kovalchik, Camerer, Grether, Plott, & Allman, 2005) that can modify their decision-making in a manner that is as flexible as younger participants (Queen, Hess, Ennis, Dowd, & Grühn, 2012). In sum, the hide-find paradigm may be appropriate for evaluating search and concealment strategies using situations that are more similar to natural situations by introducing feedback to the paradigm and being developed as a measurement tool for cognitive biases (e.g., cognitive flexibility; Kehagia, Murray, & Robbins, 2010) or aging-related alterations to cognitive biases and/or abilities (e.g., executive function; Wecker, Kramer, Hallam, & Delis, 2005).

The present results also revealed that search and concealment strategies differed dramatically, depending on partner type (e.g., social context). The present manipulation of partner type explicitly provided observers with different information about the attributes of an opponent (e.g., trustworthiness or untrustworthiness; Sutherland, Oldmeadow, & Young, 2016). However, an opponent's attributes are typically unknown in a real environment and, thus, humans sometimes have to estimate an opponent's attributes based on ambiguous nonverbal or physical cues such as facial appearance, vocal tones, career, and his/her attitude. The impressions of opponents that are obtained using these types of cues might influence finding and hiding behaviors and, furthermore, the perceived trustworthiness of a cueing person could affect selective attention and joint action (Süßenbach & Schönbrodt, 2014). Therefore, finding and hiding strategies should be investigated when participants receive these types of cues, such as an opponent's face, because some social attributes, such as trustworthiness (Todorov, Olivola, Dotsch, & Mende-Siedlecki, 2015; Todorov, Pakrashi, & Oosterhof, 2009) and intelligence (Talamas, Mavor, & Perrett, 2016; Zebrowitz, Hall, Murphy, & Rhodes, 2002), can be implicitly assumed based on facial appearance. These perceived attributes of a person might have influenced the selections made in the present study.

Although the present study examined search and concealment behaviors for visually available items, the hiding and finding of targets are not limited to this sensory modality. For example, studies of search and concealment could examine these behaviors following the presentation of non-visual items, such as stories during a conversation. It is possible to adapt the present paradigm to include non-visual items, such as stories, to determine whether a true story is easy to communicate or how a lie might spread. Unlike visually available items, a story can be directly manipulated in terms of its credibility and/or emotional value (Kensinger & Corkin, 2003). As mentioned above, the hide-find paradigm could be developed for various circumstances, which would further the current understanding of the underlying cognitive processes.

Finally, the present study revealed metacognitive estimation in the interpersonal situation and was an initial step toward identifying the essential mechanism of search and concealment underlying various aspects of daily life. For example, in a shopping mall, several products or services are sequentially provided to customers. In legal courts, the presentation order of several pieces of evidence might be critical for decision making by a jury. Such explorations would be useful to studies of persuasive communication. It is possible to examine the effect of presentation order on our choices in realistic situations. Previous studies have explored spatial search and concealment strategies in complex scenes (e.g., room; Legge et al., 2012; Talbot et al., 2009). Although the effect of spatial positioning of items on purchase is well known (e.g., center-stage effect), the visual array used in the present study did not include a definite central position because the numbers of presented items were even in all experiments. This is in sharp contrast with previous research on spatial searchers showing a well-known bias for choosing the central position. For example, during product choice, consumers prefer a product in a central position due to the belief that this product is the most popular (Valenzuela & Raghubir, 2009) or because they tend to pay attention to the product in the center (Atalay, Bodur, & Rasolofoarison, 2012). Future research should examine whether this center-stage effect would apply to search and concealment strategies in the present task.

4.4. Conclusions

The search and concealment experiments in the spatiotemporal (Experiments 1–4; Chapter 2) and temporal (Experiments 5–7; Chapter 3) domains identified five strategies. First, selection based on the saliency of an item was observed. Specifically, observers selected highly salient items (e.g., oddballs) more frequently in a friend context, whereas observers avoided selecting oddballs in a foe context. Such selection was observed in all of the spatial (Anderson et al., 2014), spatiotemporal (Chapter 2), and temporal (Chapter 3) domains examined, suggesting that observers applied common strategies because the oddball automatically attracts attention and is readily discovered by friends.

Importantly, four of the five strategies were observed when the spatiotemporal or temporal sequence contained no oddball. Second, observers selected a target for/from a foe by prioritizing a spatial component (e.g., the stack of items) rather than a serial presentation order in the spatiotemporal domain. Specifically, the results showed that the topmost stacked item was more likely to be selected for/from a friend, suggesting selection based on the perception of the ease in reaching for the stacked item (physical accessibility). Third, observers selected the target based on biases similar to recency and primacy effects specific to the temporal domain, suggesting that observers believed that the first and last items were salient. However, the second and third strategies were not involved in selection in the foe context, i.e., observers would not select the target based on the perceived difficulty in reaching for the stacked items (i.e., bottommost items) or the remaining intermediate items in the temporal sequence (e.g., items except for the first and last items). That is, the strategies differ dramatically across the partner type. Specifically, in the fourth strategy, participants selected the target based on temporal remoteness in the spatiotemporal and temporal domains, which posits that observers believed that earlier items were non-salient. This strategy was robust in the spatiotemporal domain, but was not observed in some cases during temporal search and concealment. Therefore, I argued that temporal remoteness was not always effective for selection, especially in the temporal domain, and that random selection was used in the fifth strategy. This strategy posits that placing or picking up a target in completely random positions minimizes the chance of losing the game and optimizes the probability of winning.

This study also revealed to what extent observers' selection succeeded or failed at guessing target positions by simulating the hit rates of the hiders' and finders' selections. The simulation results indicated higher hit rates in the friend context than chance, regardless of the oddball condition, suggesting that observers' intuition in both task scenarios is a common feature. In the foe context, however, the hit rates almost equaled chance, indicating that finders could not accurately estimate hiders' intentions, although hiders could successfully conceal a target.

Finally, the selection frequencies and completion times are discussed in relation to the potential mechanism of search and concealment. In this study, the saliency-based strategy for hiding and searching differed, regardless of the search and concealment domains. Specifically, observers in the seek scenario were more likely to select an oddball for a friend relative to observers in the hide scenario. This means that observers applied more complex strategies while hiding than searching because concealment behavior was linked to knowledge of search difficulty (Anderson et al., 2014; Smilek et al., 2009; Talbot et al., 2009). When observers engaged in both task scenarios and a spatiotemporal or temporal sequence contained an oddball, decision times were longer in a foe context than in a friend context. Overall, these results suggest that different cognitive processes are involved in selecting a target depending on the partner type (i.e., social context: friend or foe). I describe the processes based on observers' estimations of the finder's allocation of attention in the following two steps. In the first, observers expected that an oddball would capture the finder's attention because the oddball was reasonably salient. Intuitive (unconscious) impressions can function as a metacognitive estimation of friends' searching and hiding behaviors. In the second step, observers would estimate foes' searching and hiding behaviors based on this intuitive estimation so that salient items would be avoided. Therefore, observers required longer estimation times in the foe context because they selected the target from multiple other items (or they dared to select the oddball) by means of conscious estimation. Thus, it is possible that when observers were mentally simulating the trajectories of another's attention during searching and hiding, the presence of an oddball made this estimation easier due to the common-sense idea that the oddball should drive the initial allocation of the other's attention towards it, regardless of the task scenario or partner type.

The selections in the oddball-absent conditions would enter the second stage of the conscious estimation automatically because observers always considered all choices of the presented items with no physical cue present, such as an oddball. However, this conscious estimation was more robust in the foe context than in the friend context because each strategy in the spatiotemporal and temporal domains was straightforward and consistent across the experiments when the partner type was a friend, rather than a foe. Moreover, observers' estimation between hiders and finders was common in the friend context from the hit rate data. Therefore, when an oddball was absent, more complicated conscious estimation was required in the foe context relative to the friend context.

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ENDNOTES

[1] A portion of material from this section was originally published in:

Ito, M., & Kawahara, J. I. (2016). Contingent attentional capture across multiple feature dimensions in a temporal search task. *Acta Psychologica*, *163*, 107–113.

Ito, M., & Kawahara, J. I. (2017). Effect of the presence of a mobile phone during a spatial visual search. *Japanese Psychological Research*, *59*, 188–198.

[2] According to Cohen (1988), a w value of 0.30 is considered to be small, a value of 0.50 is considered to be medium, and a value > 0.50 is considered to be large.

[3] Each experiment in Chapter 3 included the following three steps to estimate hit rates, as previously described in Section 4.1. First, all selection data were used and randomly aligned in each experimental condition. Second, the hit rates of the selected positions between the hide and seek scenarios were calculated across the same conditions of partner type and oddball. Third, Steps 1 and 2 were repeated five times and then the mean hit rates were calculated.

OPEN PRACTICES STATEMENT

The data of the present experiments and significant program code will be made available after acceptances of original articles via the Open Science Framework (OSF; https://osf.io/4dtb9/ and https://osf.io/eucmp/). If someone including reviewers or other researchers requested access to these projects even before the acceptance, I would open them privately (please request access to my projects on the OSF website or contact me: moto.1100525 [at] gmail.com). None of the present experiments were preregistered.

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2020 年 2 月 11 日

伊藤資浩

APPENDIX A. Consent Form

実験責任者	札幌市北区北 10 条西 7 丁目 北海道大学大学院文学院 人間科学専攻 心理学講座 心理学研究室 河原純一郎
目的と方法	本研究では，人間が行う主観評価のしくみを解明することを目的として，コンピュータディスプレイなどに提示される画像や実物に対する反応（反応時間，正答率，好意度）ならびに、場合によっては眼球の運動を記録します。やって頂くことは、実験者がその都度説明いたしますので，その指示に従ってください。
実施期間	2019 年 4 月 22 日～2020 年 3 月 31 日
実験装置	通常のオフィスで使用されているものと同じコンピュータ，ディスプレイ，物品を用いる場合は市販されているもの。
実験対象者の選定条件	本実験に参加するにあたり，裸眼または矯正によって課題遂行に支障のない視力を有し，また聴触嗅味覚に健康上の問題が無い方を対象としています。
予測される研究への貢献	本実験に基づく研究成果は，学術会議や学術雑誌等への公表をとおして，人間の認知機能に関わる科学的研究の発展に貢献します。
実験対象者の受ける不利益及び危険性	実験装置は市販のものを適正に使用しており、電磁波等の影響はありません。実験中は，絶えず心身の状態に注意を払い，また、適宜休憩をとるなどに疲労にも十分配慮致します。
安全上の注意事項	実験中に何か異変を感じた場合には，直ちに実験者に申し出てください。また，安全を確保するため，実験中は実験者の指示に従って行動してください。
実験に参加しないことへの自由等	−実験への参加に同意する際には，必ず本説明を熟読し，疑問がある場合には実験者にお尋ね下さい。 −あなたには本実験に参加しない自由があります。また，参加しないことによって何ら不利益を被ることはありません。 −あなたは，実験への参加を同意した後であっても，何ら不利益を被ることなく，いつでも同意を撤回することができます。 −あなたは，実験の途中であっても，実験の中止をいつでも要求することができます。
実験対象者の権利及び人権擁護への配慮	本実験は，実験対象者の意思を尊重し，本実験に係るすべてことにおいて実験対象者が拒否する権利を認めています。また，プライバシーの保護に努めます。

個人情報の取扱い	本実験で得られた個人情報は，本実験の目的のみに使用します。個人情報は個人情報管理専用のコンピュータでのみ管理します。当該コンピュータはパスワードを設定し，鍵のかかる場所に保管します。データの閲覧は実験担当者のみとし，当該コンピュータ上でのみ行い，持ち出しは行いません。また，当該コンピュータはネットワークへの接続は一切行いません。
実験により得られたデータの取扱い及び公表の方法	研究成果の公表(論文，データベース等)には，平均値、標準偏差等の統計処理を行った後のデータのみを使用致します。個人のデータを公表する必要が場合には，個人が特定できないかたちで公表致します。本実験で得られた結果は実験責任者に帰属します。実験責任者が所属を異動した場合は，移動先の機関で結果を分析し，研究成果を報告する事があります。
知的財産権の取り扱い	本実験の成果に基づいて特許権等の知的財産権が発生した場合でも，それらの権利は実験対象者(被験者)には帰属致しません。
実験対象者からの苦情を受け付ける担当部署、担当者及び連絡方法	-担当部署および担当者: 心理学研究室主任　安達 真由美 電話 011-706-4168 電子メール m.adachi@let.hokudai.ac.jp -　連絡方法:　電話、または電子メール

上記の実験内容について、心理学実験説明書をもとに十分な説明を受けました。
特に支障がないと考えますので、当該実験に実験対象者として参加することに同意します。

年　　　月　　　日

郵便番号

住所

氏名

生年月日　　　　　年　　　月　　　日

APPENDIX B. Summary Statistics for Experiment 1

Frequencies of selecting the oddball in Experiment 1

Condition	Temporal position 1	Temporal position 2	Temporal position 3	Temporal position 4	Average
Hide × friend	56.7 [38.2–75.2]	66.7 [50.4–83.0]	71.7 [55.2–88.2]	77.1 [61.6–92.6]	68.0 [52.8–83.2]
Hide × foe	32.5 [20.2–44.8]	18.8 [9.5–28.1]	17.9 [6.4–29.4]	17.9 [7.1–28.7]	21.8 [13.1–30.5]
Seek × friend	79.2 [67.0–91.4]	76.7 [63.2–90.2]	82.5 [71.1–93.9]	89.2 [79.7–98.7]	81.9 [71.2–92.6]
Seek × foe	25.0 [14.9–35.1]	22.9 [12.3–33.5]	26.3 [15.2–37.4]	20.8 [10.4–31.2]	23.8 [14.2–33.4]

Note. Mean percentage [95% confidential intervals].

Frequencies of selecting the items under the oddball-absent condition in Experiment 1

Condition	Temporal position 1	Temporal position 2	Temporal position 3	Temporal position 4
Hide × friend	11.5 [4.1–18.9]	24.8 [12.1–37.5]	21.5 [9.9–33.1]	42.3 [24.0–60.6]
Hide × foe	50.4 [37.4–63.4]	17.1 [8.9–25.3]	9.0 [4.7–13.3]	23.5 [14.2–32.8]
Seek × friend	16.3 [9.1–23.5]	14.2 [3.0–25.4]	9.0 [4.8–13.2]	60.6 [47.5–73.7]
Seek × foe	40.8 [28.9–52.7]	22.5 [15.5–29.5]	21.5 [15.8–27.2]	15.2 [11.0–19.4]

Note. Mean percentage [95% confidential intervals].

APPENDIX C. Summary Statistics for Experiment 2

Frequencies of selecting the oddball in Experiment 2

	Temporal position				
Condition	1	2	3	4	Average
Hide × friend	63.8 [49.6–78.0]	67.5 [52.9–82.1]	71.7 [57.8–85.6]	81.7 [71.2–92.2]	71.2 [59.4–83.0]
Hide × foe	22.9 [15.0–30.8]	25.4 [16.1–34.7]	19.6 [9.7–29.5]	7.5 [2.6–12.4]	18.9 [12.4–25.4]
Seek × friend	86.7 [76.8–96.6]	84.6 [74.0–95.2]	86.7 [77.6–95.8]	94.2 [90.2–98.2]	88.0 [81.2–94.8]
Seek × foe	18.3 [11.4–25.2]	27.1 [14.5–39.7]	20.4 [11.6–29.2]	15.8 [6.5–25.1]	20.4 [14.0–26.8]

Note. Mean percentage [95% confidential intervals].

Frequencies of selecting the items under the oddball-absent condition in Experiment 2

	Temporal position			
Condition	1	2	3	4
Hide × friend	7.9 [3.5–12.3]	9.2 [2.5–15.9]	7.9 [2.2–13.6]	75.0 [62.4–87.6]
Hide × foe	39.8 [28.9–50.7]	35.6 [25.4–45.8]	12.3 [8.2–16.4]	12.3 [4.6–20.0]
Seek × friend	17.9 [6.8–29.0]	11.3 [0.0–22.8]	7.9 [2.7–13.1]	62.9 [47.2–78.6]
Seek × foe	25.8 [15.3–36.3]	44.2 [31.3–57.1]	19.0 [11.8–26.2]	11.0 [5.5–16.5]

Note. Mean percentage [95% confidential intervals].

Median completion times (ms) of selections in Experiment 2

	Oddball	
Condition	Present	Absent
Hide × friend	663 [399–927]	685 [461–909]
Hide × foe	887 [551–1,223]	789 [547–1,031]
Seek × friend	558 [419–697]	909 [625–1,193]
Seek × foe	1,115 [817–1,413]	986 [712–1,260]

Note. Means of median completion times [95% confidential intervals].

APPENDIX D. Summary Statistics for Experiment 3

Frequencies of selecting the oddball in Experiment 3

Condition	Temporal position 1	2	3	4	5	6	Average
Hide × friend	60.0 [48.0–72.0]	71.7 [58.4–85.0]	66.3 [52.9–79.7]	64.2 [49.7–78.7]	72.5 [59.4–85.6]	74.2 [59.7–88.7]	68.1 [57.1–79.1]
Hide × foe	25.4 [17.0–33.8]	15.8 [7.8–23.8]	20.8 [13.6–28.0]	16.3 [8.4–24.2]	14.6 [5.0–24.2]	14.2 [6.6–21.8]	17.9 [11.5–24.3]
Seek × friend	76.7 [66.8–86.6]	78.3 [67.0–89.6]	78.3 [65.4–91.2]	83.8 [73.3–94.3]	88.3 [78.2–98.4]	91.3 [85.2–97.4]	82.8 [73.7–91.9]
Seek × foe	15.0 [7.4–22.6]	15.0 [8.2–21.8]	10.8 [5.0–16.6]	11.7 [4.7–18.7]	11.7 [5.0–18.4]	12.5 [3.1–21.9]	12.8 [6.4–19.2]

Note. Mean percentage [95% confidential intervals].

Frequencies of selecting the items under the oddball-absent condition in Experiment 3

Condition	Temporal position 1	2	3	4	5	6
Hide × friend	15.2 [4.4–26.0]	4.4 [0.5–8.3]	4.8 [1.0–8.6]	5.6 [2.0–9.2]	7.7 [1.4–14.0]	62.3 [47.1–77.5]
Hide × foe	25.6 [15.0–36.2]	17.3 [12.5–22.1]	18.5 [8.5–28.5]	14.4 [8.9–19.9]	11.3 [7.7–14.9]	12.9 [8.1–17.7]
Seek × friend	14.6 [8.4–20.8]	3.1 [0.9–5.3]	7.7 [1.6–13.8]	4.8 [0.9–8.7]	2.7 [1.0–4.4]	67.1 [53.2–81.0]
Seek × foe	22.5 [11.6–33.4]	22.7 [12.1–33.3]	15.2 [8.0–22.4]	13.3 [8.9–17.7]	16.3 [9.8–22.8]	10.0 [6.3–13.7]

Note. Mean percentage [95% confidential intervals].

Median completion times (ms) of selections in Experiment 3

Condition	Oddball Present	Oddball Absent
Hide × friend	671 [473–869]	957 [602–1,312]
Hide × foe	1,190 [837–1,543]	1,493 [1,080–1,906]
Seek × friend	411 [333–489]	697 [556–838]
Seek × foe	830 [502–1,158]	948 [662–1,234]

Note. Means of median completion times [95% confidential intervals].

APPENDIX E. Summary Statistics for Experiment 4

Frequencies of selecting the oddball in Experiment 4

Condition	Temporal position 1	2	3	4	Average
Hide × friend	45.8 [29.5–62.1]	64.6 [50.6–78.6]	57.9 [44.2–71.6]	55.4 [38.5–72.3]	55.9 [42.8–69.0]
Hide × foe	20.8 [10.6–31.0]	20.4 [12.0–28.8]	18.3 [12.3–24.3]	25.0 [13.3–36.7]	21.2 [15.7–26.7]
Seek × friend	71.3 [61.1–81.5]	81.7 [72.6–90.8]	84.6 [78.4–90.8]	92.1 [86.4–97.8]	82.4 [76.3–88.5]
Seek × foe	24.2 [16.4–32.0]	21.3 [16.1–26.5]	17.9 [11.3–24.5]	13.3 [6.1–20.5]	19.2 [14.8–23.6]

Note. Mean percentage [95% confidential intervals].

Frequencies of selecting the items under the oddball-absent condition in Experiment 4

Condition	Temporal position 1	2	3	4
Hide × friend	40.2 [23.8–56.6]	27.3 [13.3–41.3]	13.8 [4.5–23.1]	18.8 [7.5–30.1]
Hide × foe	27.5 [14.8–40.2]	22.5 [11.8–33.2]	19.4 [9.9–28.9]	30.6 [16.5–44.7]
Seek × friend	57.7 [42.6–72.8]	8.3 [0.3–16.3]	6.7 [2.3–11.1]	27.3 [14.4–40.2]
Seek × foe	28.8 [15.8–41.8]	31.7 [21.5–41.9]	25.2 [17.7–32.7]	14.4 [8.8–20.0]

Note. Mean percentage [95% confidential intervals].

Median completion times (ms) of selections in Experiment 4

Condition	Oddball Present	Absent
Hide × friend	624 [417–831]	604 [416–792]
Hide × foe	746 [569–923]	657 [466–848]
Seek × friend	475 [367–583]	676 [505–847]
Seek × foe	946 [744–1,148]	771 [576–966]

Note. Means of median completion times [95% confidential intervals].

APPENDIX F. Summary Statistics for Experiment 5

Frequencies of selecting the oddball in Experiment 5

	Temporal position				
Condition	1	2	3	4	Average
Hide × friend	63.8 [48.1–79.5]	72.9 [60.8–85.0]	76.7 [63.8–89.6]	81.3 [71.8–90.8]	73.7 [63.5–83.9]
Hide × foe	20.8 [13.6–28.0]	23.8 [18.7–28.9]	26.3 [17.8–34.8]	25.8 [16.5–35.1]	24.2 [18.1–30.3]
Seek × friend	88.8 [83.2–94.4]	85.0 [76.6–93.4]	92.5 [88.4–96.6]	90.8 [84.3–97.3]	89.3 [84.7–93.9]
Seek × foe	22.1 [11.6–32.6]	24.2 [14.2–34.2]	20.8 [11.1–30.5]	13.8 [6.0–21.6]	20.2 [11.6–28.8]

Note. Mean percentage [95% confidential intervals].

Frequencies of selecting the items under the oddball-absent condition in Experiment 5

	Temporal position			
Condition	1	2	3	4
Hide × friend	28.3 [13.5–43.1]	11.9 [3.0–20.8]	16.5 [4.9–28.1]	43.3 [26.0–60.6]
Hide × foe	36.5 [26.7–46.3]	19.8 [13.1–26.5]	15.8 [9.9–21.7]	27.9 [17.5–38.3]
Seek × friend	36.3 [21.5–51.1]	6.7 [2.8–10.6]	9.6 [2.4–16.8]	47.5 [32.3–62.7]
Seek × foe	38.5 [26.4–50.6]	27.5 [17.0–38.0]	21.7 [13.5–29.9]	12.3 [7.5–17.1]

Note. Mean percentage [95% confidential intervals].

APPENDIX G. Summary Statistics for Experiment 6

Frequencies of selecting the oddball in Experiment 6

Condition	Temporal position 1	2	3	4	Average
Hide × friend	55.8 [39.8–71.8]	66.3 [50.4–82.2]	71.3 [56.1–86.5]	79.6 [66.5–92.7]	68.2 [54.9–81.5]
Hide × foe	25.4 [15.1–35.7]	24.6 [15.1–34.1]	25.0 [15.8–34.2]	22.1 [11.8–32.4]	24.3 [15.0–33.6]
Seek × friend	76.3 [63.5–89.1]	75.8 [63.2–88.4]	82.9 [72.1–93.7]	80.8 [70.1–91.5]	79.0 [68.0–90.0]
Seek × foe	21.3 [12.2–30.4]	19.2 [14.0–24.4]	20.8 [12.0–29.6]	17.1 [10.1–24.1]	19.6 [15.0–24.2]

Note. Mean percentage [95% confidential intervals].

Frequencies of selecting the items under the oddball-absent condition in Experiment 6

Condition	Temporal position 1	2	3	4
Hide × friend	20.4 [10.5–30.3]	8.3 [3.3–13.3]	25.4 [12.6–38.2]	45.8 [30.7–60.9]
Hide × foe	40.4 [26.6–54.2]	23.3 [16.4–30.2]	23.5 [12.9–34.1]	12.7 [7.5–17.9]
Seek × friend	31.3 [20.2–42.4]	14.0 [4.0–24.0]	7.7 [4.0–11.4]	47.1 [33.5–60.7]
Seek × foe	24.0 [16.7–31.3]	27.3 [20.5–34.1]	28.3 [21.0–35.6]	20.4 [11.8–29.0]

Note. Mean percentage [95% confidential intervals].

Median completion times (ms) of selections in Experiment 6

Condition	Oddball Present	Absent
Hide × friend	826 [489–1,163]	1,073 [625–1,521]
Hide × foe	1,173 [775–1,571]	1,149 [691–1,607]
Seek × friend	659 [409–909]	846 [508–1,184]
Seek × foe	1,422 [831–2,013]	1,295 [695–1,895]

Note. Means of median completion times [95% confidential intervals].

APPENDIX H. Summary Statistics for Experiment 7

Frequencies of selecting the oddball in Experiment 7

Condition	Temporal position 1	2	3	4	5	6	Average
Hide × friend	67.5 [52.8–82.2]	69.2 [56.0–82.4]	78.3 [66.9–89.7]	80.0 [69.4–90.6]	81.3 [71.0–91.6]	82.5 [71.1–93.9]	76.5 [65.9–87.1]
Hide × foe	13.8 [8.3–19.3]	11.3 [5.8–16.8]	12.1 [7.1–17.1]	13.8 [8.1–19.5]	13.8 [7.6–20.0]	18.8 [8.0–29.6]	13.9 [10.4–17.4]
Seek × friend	81.7 [73.0–90.4]	85.0 [78.2–91.8]	88.8 [84.3–93.3]	91.7 [87.8–95.6]	90.4 [85.6–95.2]	95.4 [91.0–99.8]	88.8 [84.8–92.8]
Seek × foe	27.9 [15.9–39.9]	22.5 [11.8–33.2]	22.9 [11.7–34.1]	28.3 [15.5–41.1]	27.1 [15.4–38.8]	23.3 [12.9–33.7]	25.4 [15.1–35.7]

Note. Mean percentage [95% confidential intervals].

Frequencies of selecting the items under the oddball-absent condition in Experiment 7

Condition	Temporal position 1	2	3	4	5	6
Hide × friend	18.3 [7.2–29.4]	4.0 [1.8–6.2]	16.3 [7.5–25.1]	12.3 [5.3–19.3]	7.5 [4.3–10.7]	41.7 [25.3–58.1]
Hide × foe	16.9 [9.7–24.1]	15.2 [10.9–19.5]	13.3 [8.0–18.6]	18.8 [12.7–24.9]	14.0 [10.0–18.0]	21.9 [10.4–33.4]
Seek × friend	43.1 [28.4–57.8]	4.6 [1.7–7.5]	11.9 [4.7–19.1]	8.5 [3.7–13.3]	5.2 [1.4–9.0]	26.7 [16.3–37.1]
Seek × foe	24.2 [13.0–35.4]	16.0 [9.0–23.0]	16.0 [10.2–21.8]	15.6 [10.0–21.2]	11.7 [7.3–16.1]	16.5 [10.2–22.8]

Note. Mean percentage [95% confidential intervals].

Median completion times (ms) of selections in Experiment 7

Condition	Oddball Present	Oddball Absent
Hide × friend	580 [450–710]	1,144 [686–1,602]
Hide × foe	1,356 [899–1,813]	1,568 [1,020–2,116]
Seek × friend	446 [361–531]	586 [450–722]
Seek × foe	774 [505–1,043]	875 [622–1,128]

Note. Means of median completion times [95% confidential intervals].

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SOURCES OF FUNDING

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