Running Head: GLOBAL & LOCAL CONTEXTUAL CUES WITH EXPERTISE

Using Global and Local Information as Contextual Cues:

Evidence from Go Expertise

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Abstract

Research on contextual cueing with real-world scenes has demonstrated that the location of task-relevant visual information can be predicted from a stable visual context, and that scene-target associations are explicitly encoded in memory. In addition, observers are biased to associate target locations in naturalistic scenes with global contexts. Less acknowledged is the possibility that observers with domain-specific expertise may form these associations differently than non-experts for scenes representative of their domain. This study contrasts the role of global and local contexts in contextual cueing for domain-specific scenes. Go board configurations serve as the domain, as their meaningfulness depends on an observer's knowledge of the game.

Using Global and Local Information as Contextual Cues: Evidence from Go Expertise

Performance on visual search tasks becomes increasingly more efficient as a result of contextual cueing, a learning effect resulting from repeated exposure to a specific arrangement of target and distractor items. This effect has been shown to reduce visual search time for simple stimulus arrays (Chun and Jiang, 1998; Jiang and Chun, 2001), as well as for naturalistic scenes (Brockmole and Henderson, 2006). It is necessary to distinguish between these forms of stimuli, as it appears that observers do not explicitly encode configurations or target locations in non-scene displays, indicating that the cueing effect is mediated by implicit memory for spatial configurations. In contrast, real-world scenes often provide substantial semantic information concerning object and scene identity, and scene-target associations are explicitly encoded in memory. As a result, scene-target associations in real-world scenes are learned up to five times faster than in non-scene displays, and have been shown to have a search time advantage twenty times greater. Previous research has demonstrated that stimulus meaningfulness contributes independently to the learning of target-scene associations (Brockmole, Hambrick, Windisch, & Henderson, 2008); in a study using displays of chess board configurations, visual search times are compared for chess experts and chess novices. For chess board configurations, meaningfulness of any given display depends on the observer's knowledge of the game. Search benefits on repeated boards were significantly greater for experts than for novices. Additionally, when less meaningful randomly generated configurations were shown, search benefits for experts were no longer apparent.

The ability to learn target locations in simple stimulus arrays and real-word scenes also differs in terms of the spatial contextual information used by observers to locate the target. The position of a target among a group of distractors in repeated non-scene displays is learned with reference to local context, rather than global context (Olson and Chun, 2002), and such local target-distractor associations are strong enough to elicit full contextual cueing (Jiang and Wagner, 2004). Conversely, in meaningful naturalistic scenes, observers tend to associate target locations with global contextual information (Brockmole, Castelhano, & Henderson, 2006). Explanation for this difference stems from the notion that global contexts in real-world scenes contain more useful information than local contexts, and that global scene gist typically guides expectations concerning the arrangement of objects within that scene (Henderson & Hollingworth, 1998). As well, changes in global scene information can significantly alter the identity of a scene, while local changes tend to preserve scene identity. While it is apparent that target positions in real-world scenes are explicitly encoded (Brockmole and Henderson, 2006), local contextual information in these scenes may still be encoded implicitly. It has yet to be determined if the precedence of global scene information for learning scene-target associations is a general property for real-world scenes. It is possible to identify several conditions in which local scene information may be as useful or more useful than global information. For instance, spatial extent of a scene determines the relative meaningfulness of global and local contexts, and the relationship between them. Previous research using scenes depicting expansive rooms has demonstrated visual search behaviour with a dependence on global contextual information (Brockmole et al., 2006). It is possible that when observing smaller-angle scenes, such as the surface of a cluttered table or under the hood of a car, local information may be more informative. In such situations, global information may be ambiguous or non-predictive, and yet scene identity may still be apparent from local information. If local information in such cases is encoded explicitly, learning target locations in repeated displays may be performed as efficiently as one would in larger scenes containing rich global information.

It is also possible that local context can be preferentially attended, becoming as useful or more useful than global context for use in visual search tasks. This is likely to occur if an observer has significant domain knowledge about a scene, thus having a greater understanding of local associations between objects. Consider again the example of an scene under the hood of a car: most people will correctly identify the global context as an engine, while those with automotive expertise may be able to correctly identify each local component and their interdependencies. Likewise, it is simpler to understand the global context of an ultrasound image, while understanding local anatomical relationships captured by the image is best understood by experts of the domain.

Previous studies support the hypothesis that experts and non-experts differ in terms of how scenes are processed and encoded. Football experts are more likely to detect changes in a scene when the change alters the semantics of the scene, such as when the ball or a player changes position or direction (Werner and Thies, 2000). Chess and Go experts encode and recall larger amounts of specialized information than novices from valid displays of game configurations, but not from meaningless random configurations (Chase and Simon, 1973; Reitman, 1976). Chess experts and novices also differ in terms of the results of visual search experiments using repeated displays of valid and invalid chess board configurations (Brockmole et al., 2008). As indicated by these previous studies, experts attend to small-scale domain-related details in a scene, and thus may be able to explicitly encode meaningful local details.

The purpose of the present study is to determine how experts and non-experts differ in terms of how they locate search targets within domain-specific scenes, and if experts use local information more effectively or as effectively as global information. The study will serve to indicate the degree to which domain experts associate search targets with local context near a target versus with the global context distant from the target. It is critical to select a domain in which scenes convey a large amount of meaningful information to experts, but not to non-experts or novices. For this reason the game of Go is used, as Go experts can derive a large amount of information from the arrangement of stones in play, while non-experts may observe the arrangement of stones as effectively as one would for a simple stimulus array of black and white shapes. Unlike chess, Go stones are uniform, with an equal number of black and white stones, while chess pieces vary in shape and frequency. Additionally, the large size of a Go board (19x19) allows for local patterns to emerge independently of the rest of the board, especially as play tends to originate from the four corners of the board, moving inwards as play progresses. Individual local patterns may also have significant effect on the balance of power between players, and a non-expert may not fully grasp the significance of different localized patterns in two globally-similar board configurations. Thus it is possible that experts encode local associations in valid board configurations explicitly, while non-experts encode local associations implicitly, as they would in non-scene stimulus arrays, especially since Go stones are uniform in appearance and frequency. In Experiment 1, we are to examine whether target positions learned by experts and non-experts transfer to situations in which local or global board configurations are altered (cf. Brockmole et al., 2006; Jiang and Wagner, 2004). In Experiment 2, local and global configurations around a target are varied, and we are to examine the extent to which experts learn target positions (cf. Brockmole et al., 2006)[1].

Experiment 1

The first experiment will examine and whether an experts' and non-experts' knowledge of a learned target position on a Go board transfers to new board configurations that differ in either their local or global context. Expert and non-expert observers undergo a series of trials on which they are instructed to locate and identify a randomly located target letter within illustrations of Go board configurations. Local context is defined as the contained patterns of stones within the board quadrant containing the target. The remainder of the configuration represents the global context. This experiment has two phases. During the learning phase, one board configuration is repeated amid a sequence of other non-repeating board configurations. Within the single repeating configuration, the target is always located in the same x,y location, although the target's identity is randomly determined in each repetition. The observers will likely learn this association over the course of several repetitions, although this is expected to occur sooner for experts. In the transfer phase, the previously repeated configuration is replaced with a transfer configuration that alters the local arrangement of Go stones near the target while preserving the global arrangement of stones distant from the target, or that alters the global arrangement of stones while maintaining the local arrangement (see Figure 1).

The full set of observers is divided into two groups, with an equal number of experts and non-experts in each group. Those in the first group observe an altered local arrangement, while those in the second group see an altered global arrangement. The stimuli shown within each group are identical, regardless of whether an observer is an expert or a non-expert.

Of interest is whether and how the earlier benefits of learning will transfer to altered configurations, and to what extent contextual cueing under this situation is affected by level of expertise with the search domain. If learning target locations is dependent upon local meaning, experts should display more significant local contextual cueing effects than that those exhibited by novices. A similar case can be made if learning locations is dependent upon global meaning. For non-experts, it is expected that any cueing effects will rely upon implicitly encoded local associations, as predicted by the results of previous research using non-scene displays (Jiang and Wagner, 2004).

It is expected that search times in both the local and global change conditions will decrease during the learning phase of the experiment, with experts learning at a faster rate than non-experts. Search time on the transfer trial will serve to indicate if experts differ from non-experts in terms of whether local or global contextual information is used to associate with the target location. Also of interest will be the difference in search time between experts and non-experts in the local change and global change groups during the transfer phase, as non-experts will likely provide a baseline performance in terms of search time in the transfer phase.

1. Method

1.1. Participants

An equal number of Go experts and non-experts are to be recruited and subsequently divided into two equal groups. All subjects must be naïve with respect to the experimental hypothesis. Non-experts should have a basic understanding of the rules of Go, and ideally should have either never played the game themselves or have an early beginner rank of 25th *kyu* or higher. Experts will have a significant history playing Go, and will have expert rankings of 1st *dan* or higher[2].

1.2. Stimuli & Apparatus

Stimuli consists of illustrations of Go board configurations. Each illustration includes a single small grey *T* or *L* presented in 9-point Arial font, which constitutes the target in a visual search task. Four critical stimuli are also created which orthogonally combine global and local arrangements into new board configurations (see Figure 1). An additional 50 unique filler configurations are also created, each of which is only shown once over the course of the experiment. All illustrations represent valid meaningful board configurations.

1.3. Design & Procedure

The method of this experiment is adapted from an experiment method used by Brockmole et al. (2006). Participants are to view 60 Go board configurations, divided into ten blocks of six trials, wherein the first nine blocks constitute the learning phase of the experiment. Participants are shown five novel filler configurations in each block. Novel configurations are used to measure baseline search time, and are described above. The remaining trial in each block is a repeated stimulus, which is the same configuration shown in each block, and is one of the four critical stimuli described above. The tenth and final block of the experiment marks the transfer phase of the experiment, containing five novel trials and a transfer trial. Since this experiment utilizes a between-subjects manipulation, the transfer trial shows a configuration which is an change orthogonal to the repeated configuration shown in the first nine blocks. Observers in the local-change group see a configuration nearly identical to the repeated configuration seen during the learning phase, except with a novel arrangement of stones near the target. Conversely, observers in the global-change group see a novel configuration of stones with the familiar arrangement of stones near the target. The target does not change position in the transfer trial. The eight different combinations of critical stimuli from training to transfer phases is counterbalanced across all subjects.

At the start of each trial, a blue dot is centred on a grey background. Observers fixate on this dot, and press a key to view the configuration when ready. When the observer locates and identifies the target, they are to press the *T* key or the *L* key on a keyboard. If the observer does not make a response within 20s of the onset of the stimulus, the stimulus is removed. No indication of block structure or repeated configurations are to be given to participants.

1.4. Predictions

Results from the learning phase of Experiment 1 are expected to indicate that repetition of configurations lead to increasingly efficient searches for both expert and non-expert observers, thus replicating the findings of Chun and Jiang (1998). It is likely that search benefits for experts will be greater than those of non-experts over the course of the learning phase; search times will be shorter for experts, and the rate of learning target locations will be faster for experts. In other words, the cueing effect will be more pronounced for experts. This is likely as experts may be able to explicitly encode configurations while non-experts, having a limited knowledge of the game of Go, will encode configurations implicitly. Results should replicate findings of Brockmole and Henderson (2006) in terms of how the presentation of meaningful repeated stimuli lead to shorter search times for the repeated stimulus. Results of the learning phase will not indicate anything about the use of local or global information for experts or non-experts. Expert observers in both groups are expected to display equivalent cueing effects, non-experts in both groups should also display equivalent cueing effects (Brockmole et al., 2006), albeit non-experts will exhibit weaker cueing effects than experts (Brockmole et al., 2008).

Comparing the cueing effect of the transfer phase with those of the later blocks of the learning phase will indicate differences between experts in the local repetition group and experts in the global repetition group, as well as between experts and non-experts in both groups. Cueing effects exhibited by non-experts in both groups will serve as a baseline for comparing against experts. It is expected that full contextual cueing will occur for non-experts in the local-repetition group, as predicted by Jiang and Wagner (2004), who will likely implicitly encode details of local association to the target location. Non-experts in the global repetition group will be unable to draw upon implicit local associations as search cues, and will likely experience a drop in search ability. The hypothesis that experts draw from local contextual information in visual search will be supported if the search time advantage achieved by experts in the local repetition group at the end of the learning phase is preserved in the transfer phase. If experts in the global repetition group also preserve the search time advantage achieved from the learning phase, it may serve as indication that experts can draw from both local and global contextual information, depending on the availability of these sources.

The result of a similar experiment using naturalistic scenes of rooms suggested that observers encode target locations relative to global scene information (Brockmole et al. 2006). The results of the current experiment may generalize this result to real-world stimuli requiring domain expertise, should the search time advantage of experts in the local repetition group be diminished in the transfer phase. Alternatively, the current hypothesis would be supported if this search time advantage is preserved, indicating that in circumstances requiring expert knowledge, target location may be associated with local information.

Experiment 2

In the second experiment, local and global board arrangements are varied independently during learning; local and global information in critical configurations are tested separately during learning. Should non-experts demonstrate slow learning rates and a dependence on local information in Experiment 1, as predicted by earlier contextual cueing research with non-scene stimuli (Olson and

Chun, 2002; Jiang and Wagner, 2004), non-experts will not be required to participate in the second experiment, which is more demanding of expert knowledge for Go configurations. Expert observers are presented with a series of trials on which they are instructed to locate and identify a randomly situated target letter. The majority of configurations shown will be novel. A subset of critical configurations to be shown will contain repeated global and/or local arrangements shown on previous trials. The full set of expert observers is divided into three groups. The critical configurations shown to the first group will repeat a local arrangement of stones near the target while arrangements of stones distant from the target are varied, meaning that the local arrangement will be predictive of the target location in such configurations. The critical configurations shown to the second group will repeat arrangements of stones distant from the target while varying the arrangement of stones near the target, meaning that the distant or global arrangement of stones will be predictive of the target location in such board configurations. The critical configurations shown to the final group repeat the entire board configuration. For all three groups, the target is always found in the same x,y location on the board in the critical configurations.

If experts rely on global contextual information, search times should decrease over many repetitions in the global repetition group. Similarly if experts rely on local contextual information, search times should decrease over many repetitions in the local repetition group, as the target will appear near the same local arrangement in a variety of global arrangements. Since both local and global information is repeated in critical configurations for the third group, search times on these trials should maximally decrease over the course of the experiment, serving as a baseline for experts performance. Of particular interest will be the differences in search time between experts in the local repetition and global repetition groups, as a large difference may be indicative of the type of contextual information used by experts.

2. Method

2.1. Participants

A group of Go experts are to be recruited and subsequently divided into three equal groups. All subjects must be naïve with respect to the experimental hypothesis and will not have participated in Experiment 1. Experts will have a significant history playing Go, and will have expert rankings of 1 *dan* or higher.

2.2. Stimuli & Apparatus

As in experiment 1, stimuli consists of illustrations of legal Go board configurations. Ten locally consistent configurations are created containing the same local arrangement of Go pieces near the target location. Ten globally consistent configurations are also created, which are globally identical except for the arrangement of pieces near the target location. An additional set of 40 filler configurations are also created in the same fashion as in Experiment 1.

2.3. Design & Procedure

The method of this experiment is also adapted from an method used by Brockmole et al. (2006). Participants observe 50 board configurations over 10 blocks, with each block containing 5 trials. In each block, four novel board configurations are shown, drawn from the set of 40 filler configurations mentioned above. Each of the 40 filler configurations are unique and are only shown once over the course of the experiment, used to measure baseline visual search time for experts. Target locations are also unique among the filler configurations. The remaining trial in each block is a repeated trial, in which a board configuration that orthogonally combines a local arrangement of stones near the target and arrangements of stones distant from the target. Those in the local repetition condition are shown configurations with novel distant arrangements and a consistent local arrangement near the target. For those in the global repetition condition, the global arrangement of stones distant from the target location is maintained while a novel local arrangement near the target location is shown. In the total repetition condition, observers see the same repeated configuration, with consistent local and global arrangement of stones. For all conditions, the search target is located in the same board location.

In all other respects, the procedure of Experiment 2 was identical to that of Experiment 1.

2.4. Predictions

Experiment 2 records search times for novel and repeated configurations over 10 blocks, with each block containing 5 trials. As predicted by earlier studies on contextual cueing, search times for novel configurations should be relatively similar across blocks (Brockmole et al., 2006). The performance on novel configurations will provide baseline search times for comparing with results from critical configurations over the course of 10 blocks. It is expected that cueing effects for critical stimuli will increase over time in each condition, with faster search times in the final block than in earlier blocks. The purpose of this experiment is to contrast the size of cueing effects, as well as the rate of increase in size, between the three conditions. Size of cueing effects in the total repetition condition will serve as an upper bound for the size of cueing effects observed in the local and global repetition conditions. As per the hypothesis, if experts can preferentially attend to local information, the size and rate of increase of the cueing effect in the local repetition condition will be as pronounced or more pronounced than the effect produced by observers in the global repetition condition. Conversely, smaller and slower developing cueing effects in the local repetition condition will indicate that experts do not rely on local information as much as they do global information.

In a similar experiment using animated room scenes (Brockmole et al., 2006), it was presumed that observers associate target positions with local information when global information is not predictive. This was inferred from increasing cueing effects exhibited by observers in the local repetition, however the rate of increase was lower than the rate of increase for observers in the global repetition condition. However in the current experiment, board configurations contain substantial meaningful data at the local level, which experts must preferentially attend to, suggesting that local information will be of considerable use to experts.

General Discussion

In this proposed study, the contextual cueing effect for expert observers is to be examined, as well as the degree to which this effect depends upon learned associations with local patterns (near the target), global patterns (distant from the target), or a combination of both types of patterns. Of particular interest is whether experts can use local information when global information is not predictive of target locations. Such a domain where this may occur is within the game of Go, which requires considerable expert knowledge of global and local structure. On the other hand, non-experts and those unfamiliar with the game will find it difficult to distinguish between Go board configurations, as very little identifying information can be extracted from any individual piece. In the first experiment, two groups, both containing expert and non-expert observers, search for a target in novel and repeated illustrations of Go board configurations. This process allows observers to learn the position of the target in repeated configurations. In the transfer phase of this experiment, local arrangements of Go stones near the target are divorced from the global arrangement of pieces. One group of observers is shown a new global configuration of stones with a familiar arrangement near the target position, while the other group is shown a new arrangement of stones near the target within a familiar global arrangement. A transfer of learning is expected for non-experts when local information is repeated, but not when local information is altered (Jiang and Wagner, 2004). A transfer of learning is expected for expert observers is expected in both conditions, as it is believed that experts can preferentially attend to meaningful local information when global information is not predictive of target location. In the second experiment, three groups of experts observe a series of board configurations, among which the global and local arrangements of several critical stimuli are manipulated independently during learning. For critical stimuli in the local repetition group, experts see a familiar arrangement of stones near the target location within a variety of global configurations.

For critical stimuli in the global repetition group, observers see a variety of novel arrangements of stones near the target location within a familiar global arrangement. An unchanged board configuration is the critical stimulus shown to the total repetition group. The effect of expertise is likely to be beneficial to visual search (Brockmole et al., 2008). Since board configurations are legal representations of game-play, experts will be able to draw semantic meaning from each configuration, and thus be able to explicitly encode associations with target locations. A previous study in contextual cueing with meaningful scenes suggests that contextual cueing effects will be observed in the global, local, and total repetition conditions (Brockmole et al., 2006). It is predicted for this study that experts will not experience a loss in visual search performance when global information is non-predictive, as they may preferentially attend to local information in such situations.

For the purposes of discussion, let us assume that the results of these experiments support the hypothesis that experts can preferentially attend to local information to guide visual search. This may occur in cases when global information is not predictive enough to locate a target. Alternatively, experts may choose to attend to local information when local patterns are more indicative of scene identity. For example, a local arrangement of Go stones may represent a pivotal power struggle between two players in the early or middle phases of the game. This local structure may be vital in directing the global arrangement of stones later in the endgame. Unlike arbitrarily arranged letter displays, the game of Go imposes a structure on the arrangement of elements in a board configuration. However, this structure may be visible only to those with knowledge of the rules of Go and the strategic placement of stones. Otherwise, the homogeneity of the elements in any given board configuration is similar to that of a simple stimulus array. The arrangement of elements in naturalistic scenes, such as rooms, also impose expectations as to the arrangement of objects within the scene. Objects must obey physical constraints, licensed by the global spatial properties of the scene (Henderson & Hollingworth, 1999). The global semantic expectations of a scene, or scene gist, also give rise to our expectations of what objects are likely to occur locally within a scene. If we can consider ourselves as expert observers of room scenes, such as those used in the previous study by Brockmole et al. (2006), we can infer that observers seem to use these globally-defined rules to guide our visual search in places where the global identity is easily understood. However in circumstances requiring expert knowledge at the local scale, as in the case of the locally-imposed rule structure of Go, observers may require local information to guide our visual search.

A skilled Go player will have abundant knowledge of frequently occurring local patterns, such as *ko*, *ladders*, *eyes*, *false eyes*, and *dead* and *alive* arrangements of stones (Fairbairn, 1977). Experts can explicitly recognize these familiar local arrangements, and they may provide better or equally as powerful retrieval cues as global arrangements. Such salient patterns may "pop-out" for experts, helping overcome confusion as a result of changing global contexts. This could be verified should the results of Experiment 1 indicate that local context is a more powerful resource to expert observers than global context.

Another important distinction between Go board configurations and displays of large spaces is the spatial extent of the scene. A Go board is a 2-dimensional surface on which stones must obey locally-constrained rules. In this situation, the global context has very little usefulness on its own, and thus players must concentrate on local events. In contrast, the global context of larger spaces may be very helpful in activating schemas which are used to infer the presence of local objects in the scene.

One significant limitation of this proposed experiment is the fact that many high-ranking Go players, and an overwhelming majority of professional Go players, have an East-Asian background. As a result, the recruiting of participants may need to occur in an East-Asian country in which novice and expert Go players are more easily located. Participants in previous real-world contextual cueing experiments have been recruited from American (Brockmole et al., 2006) or Scottish (Brockmole, et al, 2008) cultural settings. This creates a problem as it is speculated that differences in cultural environment affect perceptual abilities (Miyamoto, Nisbett, & Masuda, 2006). As such, the results of these prior experiments may need to be replicated in an Eastern cultural environment before making any conclusions about the perceptual abilities of experts in general, regardless of cultural background.

Many real-world environments require extensive domain knowledge to fully comprehend, and may require familiarity with local patterns while relying less on global patterns. For example, consider heat map visualizations obtained from DNA microarray data, as used in the field of molecular biology to assess gene expression levels. Those with domain expertise may very well be able to detect local clusters in the data, and be able to dynamically adjust their scope of attention to best suit the task at hand. A similar conjecture can be made about expert Go players. The hypothesis that experts dynamically shift between using local and global contexts should seem familiar to everyday computer users, who are able to constantly readjust their self-perceived sense of global and local context when navigating directory structures and other interfaces. Such navigation tasks place demand on our contextual awareness and can be difficult for non-computer users. Future research dedicated to the study of expertise and visual search is required to fully understand how experts and non-experts differ in terms of how context is used in these complex environments. This research may contribute significantly to the development of computer interfaces and visualization techniques that do not require a dynamic or expert-level ability of contextual awareness.

In conclusion, this proposed study will examine how experts use contextual cueing to guide visual search in demanding real-world scenes. Previous research has identified differences in contextual cueing effects between experts and non-experts, as well as differences in contextual cueing effects between non-scene stimuli and real-world scenes, in terms of how observers rely on global and local information within a display. The current study aims to examine both of these differences simultaneously, as research in other areas of scene perception has indicated many ways that experts and non-experts differ in how they interpret and encode scenes.

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Figures

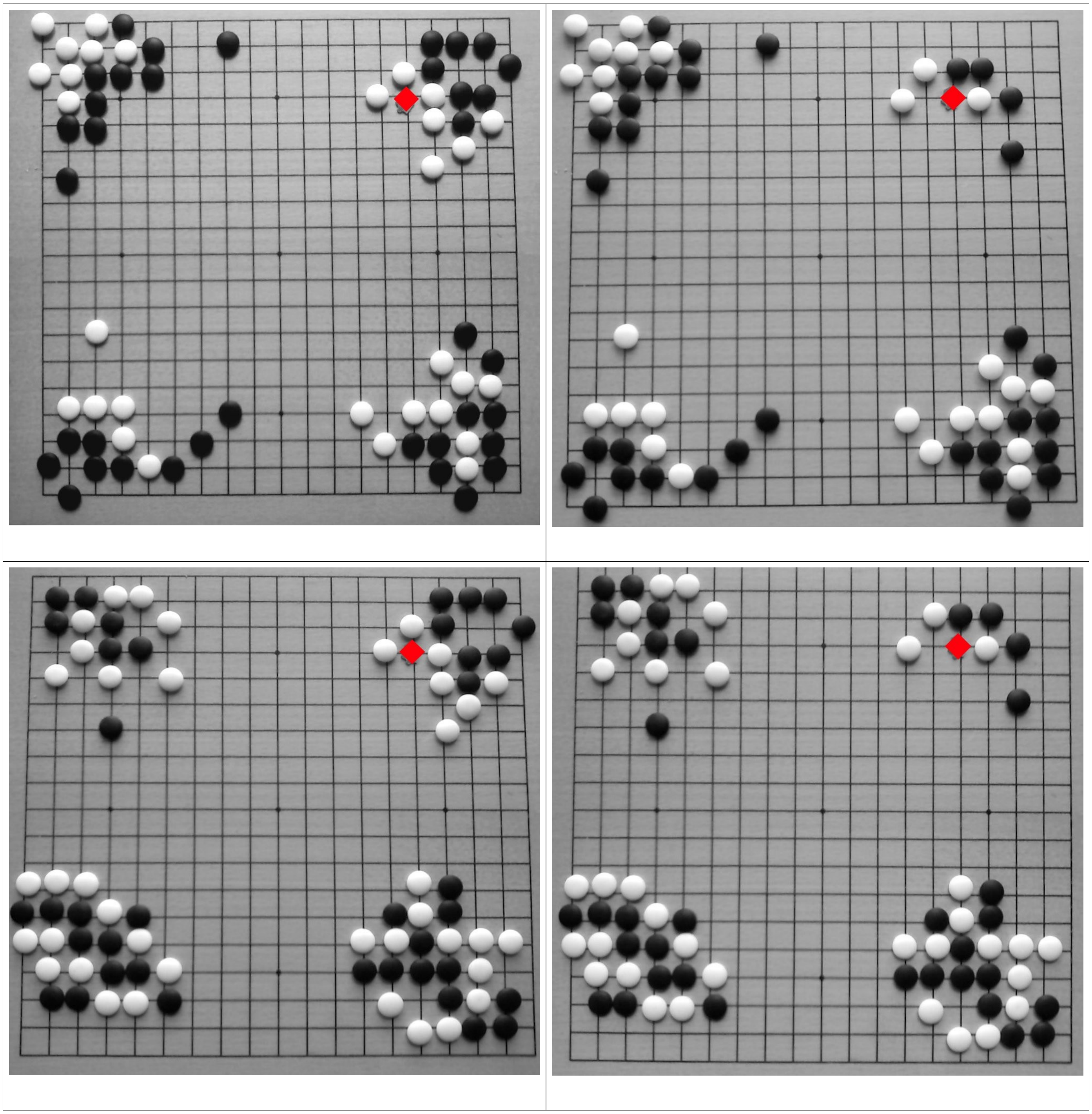

Figure 1: example of an orthogonal set of Go board configurations (target position marked in red)

1 In both experiments, all novel, repeated, and manipulated board configurations represent valid configurations, as it is presumed that invalid configurations would lead to an overall degradation of performance by experts (Brockmole et al., 2008), and would not serve to answer the question of how experts use global and local information.

2 See Fairbairn (1977), who explains how Go ranks are measured using *kyu* (k), *dan* (d) and professional *dan* (p). *Kyu* ranks are higher for beginners (starting at 30k) and lower for intermediate players (ending at 1k). *Dan* ranks are given to expert increasing with skill level from from 1-7d, then from 1-9p for professional players.