Visual search characteristics of precise map reading by orienteers

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This article compares the differences in eye movements between orienteers of different skill levels on map information searches and explores the visual search patterns of orienteers during precise map reading so as to explore the cognitive characteristics of orienteers' visual search. We recruited 44 orienteers at different skill levels (experts, advanced beginners, and novices), and recorded their behavioral responses and eye movement data when reading maps of different complexities. We found that the complexity of map (complex vs. simple) affects the quality of orienteers' route planning during precise map reading. Specifically, when observing complex maps, orienteers of higher competency tend to have a better quality of route planning (i.e., a shorter route planning time, a longer gaze time, and a more concentrate distribution of gazes). Expert orienteers demonstrated obvious cognitive advantages in the ability to find key information. We also found that in the stage of route planning, expert orienteers and advanced beginners first pay attention to the checkpoint description table. The expert group extracted information faster, and their attention was more concentrated, whereas the novice group paid less attention to the checkpoint description table, and their gaze was scattered. We found that experts regarded the information in the checkpoint description table as the key to the problem and they give priority to this area in route decision making. These results advance our understanding of professional knowledge and problem solving in orienteering.

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Abstract

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levels on map information searches and explores the visual search patterns of orienteers during
precise map reading so as to explore the cognitive characteristics of orienteers' visual search.
We recruited 44 orienteers at different skill levels (experts, advanced beginners, and novices),
and recorded their behavioral responses and eye movement data when reading maps of
different complexities. We found that the complexity of map (complex vs. simple) affects the
quality of orienteers' route planning during precise map reading. Specifically, when observing
complex maps, orienteers of higher competency tend to have a better quality of route planning
(i.e., a shorter route planning time, a longer total fixation time, and a more concentrate
distribution of fixations). Expert orienteers demonstrated obvious cognitive advantages in the
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orienteers and advanced beginners first pay attention to the checkpoint description table. The
expert group extracted information faster, and their attention was more concentrated, whereas
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34   orienteering.

35

Introduction

37   Orienteering is a sport in which orienteers take a map and a compass and run to reach some
38   points marked on a map as soon as possible (Eccles, Walsh, & Ingledew, 2002a). It places high
39   demands not only on orienteers' physical fitness and strength but also on cognitive capabilities,
40   such as attention, visual search, and decision-making. Route planning based on map
41   information is an essential skill for orienteers. Therefore, map reading ability directly affects
42   orienteers' performance. There are dozens of directional map symbols, representing different
43   landforms and terrain features. However, not all map symbols have navigational functions.
44   Recognizing all the details on the map greatly reduces the speed of march in orienteering
45   (Robertson, Egly, Lamb, & Kerth, 1993). Therefore, the efficiency of map reading is important
46   for orienteers to obtain the key information within a limited time (Muñoz-Nieto, Rodríguez-
47   Gonzálvez, González-Aguilera, & Mancera-Taboada, 2013; Pesce, Cereatti, Casella, Baldari,
48   & Capranica, 2007). Therefore, the capability of visual searching can help orienteers quickly
49   and efficiently recognize, process, and code the information on the map and to quickly and
50   accurately find the key information in route planning (Henderson & Hollingworth, 1999;
51   Henderson, & Pierce, 2008). Eccles et al. (2002b) and other scholars applied the grounded
52   theory in interviewing professional orienteers and put forward the cognitive theory of
53   orienteering. From their research, we find that orienteers of expert competency can flexibly use
54   a variety of skills to quickly identify map information and accurately extract pertinent
55   information. A case study by Macquet, Eccles, and Barraux (2012) points out that expert
56   orienteer can simplify the navigational information to improve the efficiency of their route
57   planning. For example, an orienteer will first select easily identifiable map information and
58   quickly determine the checkpoints. As the training increases, orienteer's ability of map reading
59   is gradually developed and improved. Therefore, it is of great interest to examine the
60   characteristics of map reading for orienteers at different levels, to summarize the differences in
61   the visual attention of orienteers with different levels of experience in map reading, and to
62   analyze the attention strategies of expert orienteers, in order to better select and train
63   orienteers.

64   At present, most existing research focuses on the visual search feature of reasonable route
65   selection between points on the map. Through interviews and questionnaires, it has been found
66   that excellent orienteers choose obvious landforms and terrain features as "assistants" when
67   planning a route (Macquet et al., 2012; Seiler, 1990). Eccles et al. (2002a, 2002b) summarized
68   the visual search characteristics of expert orienteers by analyzing their self-statements about
69   route planning and the experimental manipulation of the map board. It has been found that
70   expert orienteers first focus on the information around the terminal point, whereas novice
71   orienteers first focus on the information around the starting point. With the development of eye
72   movement technology, the visual search strategy of orienteers can be measured more precisely
73   as compared with the research methods of interview and self-report. Zhu and colleagues
74   (2011) conducted eye-tracking research on competent players and novices, the results of which

75   are consistent with those obtained from interviews (Eccles & Arsal, 2015). This research found
76   that expert orienteers have a strong ability to simplify maps and focus only on the information
77   related to the task. In previous research (Liu Y.,2018), the author systematically studied the
78   general map reading of orienteers through eye movement technology and found that the map
79   type and information quantity (i.e., map complexity) restricted the visual search and route
80   planning of orienteers so that orienteers at different levels showed different visual search
81   characteristics. Systematic evaluation of eye tracking shows that high-level orienteers have
82   cognitive advantages in their visual search ability (van der Gijp et al., 2017). When reading
83   simple maps, orienteers in the advanced beginner group and expert group tend to start
84   searching from the beginning point, whereas when reading complex maps, orienteers in the
85   expert group tend to start searching from the checkpoint description table.

86   In orienteering, it is necessary to investigate the visual search characteristics of precise map
87   reading in which orienteers have approached a point and have to determine the exact location of
88   point. Specifically, precise map reading requires orienteers to carefully identify and distinguish
89   the information near a point and successfully reach the point (Figure 1). In orienteering
90   competition, the accuracy of the maps is also the key to successfully completing the route. In
91   the present study, we adopt precise maps of different difficulties and measure the eye
92   movement characteristics of the orienteer while searching for map information in order to
93   explore the visual search characteristics of orienteers at different skill levels. The hypothesis is
94   that experts, advanced beginners, and novices will be affected differently by the difficulty of the
95   task during precise map reading and will have different visual search characteristics and
96   processing features.

97

Methods

Participants

100 A total of 44 participants were invited to take part in the research, including 12 expert
101 orienteers with an average age of 22.3 years, all of whom were active national orienteers at a
102 skill level of class I or above, 16 advanced beginners with an average age of 21.2 years, all of
103 whom were orienteers on a high-level university team at a skill level of class II or above, and
104 16 novice orienteers with an average age of 20.6 years, all of whom were students in an
105 optional course of orienteering and had play orienteering for more than half a year. All
106 participants had normal or corrected-to-normal visual acuity in their left and right eyes and
107 were able to master the basics of orienteering. None had participated in similar experiments
108 before. Informed consent was obtained from each participant. The study had been approved by
109 the Ethics Committee of Shanxi Normal University.

Materials and design

111 A 3 (Competency level of orienteer: novice, advanced beginner, or expert) × 2 (map
112 complexity: simple or complex) two-factor mixed experimental design was adopted for this
113 research. Competency level of the orienteer was the between-subjects factor and the map

114   complexity was the within-subject factor. The simple map was a park scene at a scale of
115   1:4000 and the map information was composed mostly of landform features such as buildings.
116   The complex map was a wilderness scene at a scale of 1:10,000 and the map information was
117   mostly terrain features such as mountains. Three professors of orienteering were asked to rate
118   the complexity of the selected maps on a 5-point scale from 1(very simple) to 5 (very
119   complex). According to the ratings of these professors, 14 simple maps and 14 complex maps
120   were selected (2 maps were used as practice maps, and the remaining 12 maps were used as
121   experimental materials). All experimental maps were based on actual scene maps used in a
122   national orienteering competition and then redrawn by three national-level cartographers. The
123   distance between points on all maps was 2–3 cm.

Apparatus

125   The Eyelink 1000 Plus eye tracker, with a sampling rate of 1000 Hz, was used in the present
126   experiment. The stimuli were displayed on a 17-inch CRT computer screen with a refresh rate
127   of 85 Hz and a screen resolution of 1024 × 768 pixels. The distance between participants' eyes
128   and the screen was approximately 60 cm. The laboratory was in a low-illumination
129   environment. To reduce the effect of head movement on eye movement tracking, participants
130   placed their jaws on the mandible holder at a proper height.

Procedure

132   The experiment required participants to read the map and plan route as if competing in a real
133   competition. Before the formal experiment, the participants filled out a basic questionnaire
134   prepared by the research team and the gender, age, training years, skill level, and other basic
135   information about the participants was recorded. The experiment procedure is depicted in
136   Figure 2.

137   The experimental procedure was run by the E-Builder software provided by the SR Research
138   Company. At the beginning of each trial, a small dot (drift correction) first appeared at the
139   center of the screen. When the fixation of the test subject coincided with the small dot, the
140   small dot disappeared and then the map was displayed. In the experiment, the subject was
141   required first to read the presented map, and then plan a route they think was the best and
142   remember it (stage of route planning). After the orienteer completed the planning, they were
143   asked to press the "space bar" to make the map disappear. The route planning time was
144   recorded by the computer. Next, the center of the screen presented a 200ms prompt – "Please
145   use your eyes to scan the route you have just planned." And then the map was presented again.
146   The orienteer was asked to quickly scan their planned route with their eyes on the map (stage
147   of route scanning). After the scanning was completed, the orienteer would press the "space
148   bar" and the map disappeared. There were 4 practice trails (two simple and two complex
149   maps) before the formal experiment to ensure that the participants fully understood and were
150   familiar with the experimental process. The formal experiment was completed in a total of 24
151   trials and the simple and complex maps were randomly presented in all trials.

Data processing

153   The original eye movement data was processed with a Data Viewer package provided by the
154   SR Research Company. For eye movement data in the route planning stage, the researchers
155   first removed the fixation point (i.e., the fixation identified by the eye tracker) outliers with
156   fixation duration of less than 80 ms or more than 800 ms. The remaining data were analyzed
157   through SPSS 17.0 statistical software package. The eye movement indicators included the
158   number of fixations, the average fixation frequency, and the fixation track. Finally, the
159   researchers organized each participant's eye movement tracks for each trial stage into a video
160   file in AVI format. Then we invited the three professors of orienteering to evaluate the quality
161   of the route (i.e., fixation point track) the orienteer planed on a 5-point scale, and we used
162   average of scores given by the professors as the indicator of quality of route planning. We
163   focus on three eye movement indicators, i.e., total fixation time, fixation frequency, and
164   positions of the first five fixation points. The total fixation time refers to the total duration of

165   all fixations in the stage of route planning.   The fixation frequency refers to the number of
166   fixation per second in the stage of route planning. The distribution of the first five fixation
167   points refers to the positions of the first five fixation points on the map in the stage of route
168   planning. We also showed the Heat map to show the distribution of the fixations in the stage of
169   route planning.

Results

171   **Behavioral indicators**

172   **Comparison of quality of route planning**

173   For each trial, the participant's eye movement track in the stage of route scanning was stored
174   in a video file and three professors of orienteering were asked to evaluate the quality of the
175   planned route by each orienteer on a 5-point scale. The average score of the evaluation was
176   showed in Table 1. A 3 (Orienteer level: novice, advanced beginner, or expert) × 2 (map
177   complexity: simple or complex) two-factor analysis of variance (ANOVA) found that the
178   effect of orienteer level [$F(2, 41) = 15.991, p < .001, \eta^2 = 0.438$] and map complexity [$F(1, 41)$
179     $= 26.198, p < .001, \eta^2 = 0.390$] were both significant, and the two-way interaction was also
180   significant [$F(2, 41) = 4.098, p < .05, \eta^2 = 0.167$]. Simple effect analyses showed that under
181   the simple map condition, the main effect of the orienteer level was not significant [$F(2, 41) =$
182     $1.528, p > .05, \eta^2 = 0.069$], whereas under the complex map condition, the effect of orienteer
183   level was significant [$F(2, 41) = 16.219, p < .001, \eta^2 = 0.442$]. The Post Hoc multiple
184   comparisons for the effect of orienteer level under complex map condition showed that the
185   quality of route planning in the novice group was significantly lower than that of the advanced
186   beginner group ($t = 3.75, p < .001$) and the expert group ($t = 5.56, p < .001$), and that of the
187   advanced beginner group was significantly lower than that of the expert group ($t = 2.09, p <$
188   .05). (See Figure3)

189   **Comparison of route planning time**

190   A similar 3 × 2 two-factor ANOVA found that the effect of orienteer level [$F(2, 41) = 8.387, p$
191     $< .01, \eta^2 = 0.290$] and map complexity [$F(1, 41) = 6.134, p < .05, \eta^2 = 0.130$] were both
192   significant, and the two-way interaction was also significant [$F(2, 41) = 3.369, p < .05, \eta^2 =$

193   0.141]. Simple effect analyses showed that under the simple map condition, the effect of
194   orienteer level was not significant [$F(2, 41) = 2.120$, $p > .05$, $\eta^2 = 0.094$], but under the
195   complex map condition, the effect of orienteer level was significant [$F(2, 41) = 10.226$, $p <$
196    $.001$, $\eta^2 = 0.333$]. The Post Hoc for the effect of orienteer level under complex map condition
197   showed that the route planning time of the novice group was significantly longer than that of
198   the advanced beginner group ($t = 3.12$, $p < .05$) and the expert group ($t = 4.35$, $p < .001$),
199   whereas the difference between the advanced beginner group and the expert group was not
200   significant ($ps > .05$). (See Table 2 and Figure 4)

Eye movement indicators

Total fixation time

203   The 3×2 two-factor ANOVA indicates that both the effect of orienteer level [$F(2, 41) =$
204   5.047, $p < .05$, $\eta^2 = 0.198$] and that of map complexity [$F(1, 41) = 4.794$, $p < .05$, $\eta^2 = 0.105$]
205   were significant, as was the interaction between the two [$F(2, 41) = 6.437$, $p < .01$, $\eta^2 = 0.239$].
206   Simple effect analyses indicated that the effect of orienteer level was not significant in the
207   simple map condition [$F(2, 41) = 7.819$, $p < .05$, $\eta^2 = 0.276$] but was significant in complex
208   maps [$F(2, 41) = 7.819$, $p < .05$, $\eta^2 = 0.276$]. The post hoc for the effect of orienteer level in
209   the complex map condition found that the expert group showed longer total fixation times than
210   the advanced beginner group ($t = 2.51$, $p < .05$) and novice group ($t = 3.91$, $p < .001$) and that
211   there was no significant difference between the total fixation times in the advanced beginner
212   group and in the novice group ($ps > .05$). (See Table 3 and Figure 5)

Fixation frequency

214   The 3×2 two-factor ANOVA indicates that the effect of orienteer level [$F(2, 41) = 0.256$, p
215    $> .05$, $\eta^2 = 0.012$], the effect of map complexity [$F(1, 41) = 0.148$, $p > .05$, $\eta^2 = 0.004$] and the
216   two-way interaction [$F(2, 41) = 0.364$, $p > .05$, $\eta^2 = 0.017$] were all nonsignificant. The results
217   suggest that there was no difference in the fixation frequency when orienteers of different skill
218   levels read maps. (See Table 4 and Figure 6).

Distribution of the first five fixation points

220   We compared the differences in the features of visual search via inspecting the distribution of
221   the first five fixation points between orienteers at different skill levels. The first five fixation
222   points of the novice group all fall between the starting point and the terminal point. The first
223   five fixation points in the advanced beginner group fall on the checkpoint description table.
224   The first five fixation points in the expert group fall on the checkpoint description table and
225   the terminal point. As shown in Figure 7, the expert group and advanced beginner group start
226   from the checkpoint description table, but the expert group shows fewer fixation points than
227   the advanced beginner group, which demonstrated a higher map reading efficiency; the novice
228   group starts to search among spots in the map, with a special focus on the information between
229   the starting point and the terminal point.

Heat map of fixation distribution

231 Figure 8 gives three typical examples of fixation distribution in a map of a given complexity.
232 Spots at which orienteers of different skill levels fixated are highlighted in green, yellow, and
233 red. The green–yellow–red color scheme is used to represent the frequency of fixation, with
234 green indicating the lowest frequency, yellow the intermediate frequency, and red the highest
235 frequency. Through a comprehensive analysis of the fixation point distribution heat maps of
236 orienteers at different skill levels, it can be seen that the more capable the orienteers are, the
237 smaller the area they are likely to search. The red spots of the novice, advanced beginner, and
238 expert groups are concentrated mostly at the terminal point. In terms of the duration of
239 fixation, the expert group spends less time on the checkpoint description table than the
240 advanced beginner group, whereas the novice group spends none, indicating that the expert
241 group has higher map reading efficiency.

Discussion

Analysis of orienteers' route planning accuracy

244 A detailed analysis of the quality of route planning shows that novice, advanced beginner, and
245 expert groups all show less accuracy in route planning in complex maps than in simple maps.
246 This means that the performance of orienteers at different skill levels is subject to the
247 complexity of the maps, which was consistent with what has been discovered in sketch map
248 reading studies (Liu & He, 2018; Zhu et al., 2011). Visual search generally needs to be done
249 through top-down target attention and feature identification (Wolfe & Horowitz, 2017). When
250 the cognitive demand in a scenario increases, the limitations of visual attention processing will
251 increase the time needed to make decisions (Zhou & Liu, 2010). In simple precise map reading
252 scenarios, cartographic information is basically about houses. In complex maps with brown
253 contours as geomorphic indicators, more information is included, posing more challenges to
254 orienteers as they must identify a lot of information carefully; this leads to much more effortful
255 information processing and slows down the route planning speed.

256 Prior research demonstrated that long-term training can speed up and improve decision making
257 (Liu & He, 2016). As for orienteering, providing long-term training in knowledge and skills
258 will better regulate the structure and sequence of information processing. Meanwhile, the
259 ability of low-level orienteers to identify key information is subject to their working memory
260 capacity (Eccles et al., 2002a). Therefore, novice orienteers are more likely to be influenced by
261 the complexity of maps, which results in a worse performance than that in the expert group.

Analysis of orienteers' visual search efficiency

263 Visual search efficiency is determined by route planning time and fixation frequency. Route
264 planning time shows how much information is processed by the orienteer; the longer it takes,
265 the less efficient information processing is thought to be. The fixation frequency refers to the
266 number of fixation per unit time, which can be regarded as the processing speed of the map
267 search; the more capable the orienteer is, the more information he or she can obtain and store,
268 and the more efficient information processing is; in other words, more information is obtained
269 per unit time (Wiley & Jarosz, 2012).

270   According to our findings, in complex maps the advanced beginner group and expert group
271   spent less time on route planning than the novice group, which indicates that expert orienteers
272   are better at gathering and processing information and thus have higher visual search
273   efficiency (Ericsson & Lehmann, 1996). Eye-tracking data for orienteers' precise map reading
274   reveals that task difficulty can differentiate the total fixation times between the expert,
275   advanced beginner, and novice groups. Excellent orienteers can gather useful information
276   using an effective fixation and ignore useless information, saving more time for important
277   zones.

278   This characteristic likely develops because expert orienteers have acquired sophisticated skills
279   over time and may be better at visual search (Eccles, Walsh, & Ingledew, 2006). For example,
280   their experience can help reduce the cognitive load in information processing so that they can
281   better search for information quickly (Williams, 2000), encode valuable information efficiently
282   (Baber, & Butler, 2012; Eccles, 2008), and flexibly adopt various features (Eccles & Arsal,
283   2015). Novice orienteers are less efficient in map searching and cannot quickly identify
284   valuable information. Therefore, they do not have an advantage in the cognitive processing of
285   specific information.

286   It takes three-dimensional thinking to understand cartographic signs on complex contour maps.
287   It is more difficult to identify cartographic signs on complex maps than on simple maps
288   because of dimensionality. Our eye movement data revealed that map complexity
289   differentiates the visual search efficiency of the orienteer.   Complex maps pose more
290   challenges to the visual search efficiency of the orienteers. With the growing complexity of
291   maps, more cognitive effort is required from the orienteer that occupies a large proportion of
292   the cognitive capacity and they need to store and retrieve information to and from memory,
293   leading to a longer duration for information retrieval and identification (Rinck, Becker,
294   Kellermann, & Roth, 2003).

295   **Analysis of orienteers' visual search patterns**

296   A visual search pattern is the way orienteers search for useful information. More specifically,
297   it refers to the trajectory of the fixation formed by the connection of each fixation point, as
298   well as the heat map of the fixation, both of which exhibit the search characteristics of the
299   orienteer. During precise map reading, subjects' visual search patterns display identical
300   features as those in sketch map reading (Eccles et al., 2006; Liu & He, 2018; Zhu et al., 2011).
301   The higher the skill level of the orienteer, the smaller the area the fixation will cover. Fixation
302   distribution become more concentrated as their orienteering skills improve. Skilled orienteers
303   tend to pay more attention to the changeable information, because they can efficiently shift or
304   allocate their attention to reduce the cognitive load for processing information so as to resist to
305   the constraints (Joseph, Keehn, Connolly, Wolfe, & Horowitz, 2009). The distribution of
306   novice orienteers' fixations was pretty scattered. Another important finding of this study is the
307   difference in visual search of the checkpoint description table between orienteers of different
308   skill levels. Through the trajectory of the first five fixation points, we found that the expert
309   group starts at the checkpoint description table so that they can gather the point information
310   and then extract key information around the points. Advanced beginners show a similar pattern

311 of visual search, but they produce more fixations than experts, which indicates that there are
312 differences between orienteers of the two skill levels in terms of familiarity and understanding
313 of the checkpoint description table. The novice group fixates back and forth between the
314 starting point and the terminal point, leading to a scattered, deconcentrated fixation trajectory;
315 the first five fixation points are not on the checkpoint description table either. Heat maps of
316 fixation distribution also indicate the importance of the checkpoint description table, in which
317 we find that the expert group's fixations cover more areas of the map than those of the
318 advanced beginner group despite their fixation distribution to the checkpoint description table.
319 This was an indication of swift information retrieval by expert orienteers. The novice group
320 gives no attention to the checkpoint description table. The checkpoint description table is a
321 detailed illustration of where the points are and defines their features. This was a useful guide
322 for orienteers to seek the best routes as quickly as possible. Gasser (2016) pointed out that the
323 checkpoint description table is crucial for orienteers' performance in orienteering. The study
324 also finds that experts outperform orienteers of other skill levels in map reading around the
325 checkpoint description table with a higher efficiency of visual search.

326 To maximize the potential of the orienteer, the selection and training of orienteers are both
327 important (Newton, & Holmes, 2017). This finding reminds us that we should increase the
328 familiarity of the orienteer with the map information during training. More legends and
329 information are contained in complex maps, and thus novice orienteers are not able to
330 understand the information. Therefore, it is necessary to train them to be familiar with the map
331 so as to gain more experience and understand the information more quickly. Meanwhile, it is
332 necessary to train them in identifying and attending to the checkpoint description table.
333 Advanced beginners' understanding of information in the checkpoint description table should
334 be increased as well so they can effectively gather the information in the checkpoint
335 description table. Previous studies have shown that teaching novices specific cognitive
336 processing skills can improve their orienteering skills, such as positioning and using specific
337 clues in a certain environment (Singer et al., 1994). Therefore, it is feasible to design an
338 efficient route toward the terminal point by training novice orienteers to pay attention to the
339 checkpoint description table.

340 This study also has a limitation. It was carried out in laboratory, so its ecological validity needs
341 further examination. Participants reported that their route planning in the experiment was
342 similar to, yet still different from, real-life situations. For example, studies have revealed that
343 pressure will influence orienteers' performances of memory (Robazza et al., 2018) and
344 attention (Eccles et al., 2006) in map reading in running. Moreover, attention shifts between
345 the map and the environment (Mottet, Eccles, & Saury, 2016; Pesce et al., 2007) will influence
346 the visual search patterns of novice and expert orienteers and the result of the competition.
347 Therefore, time and space can be introduced in future studies to improve their authenticity and
348 thus improve ecological validity.

Conclusions

350 The present study shows that the complexity of a map influences orienteers' route planning in
351 precise map reading. In complex maps, the higher skill level of the orienteers, the higher score
352   they can get on route planning and the more efficient their visual search. The novice group
353   spends more time on route planning than the expert and advanced beginner groups and expert
354   orienteers show more cognitive strength in seeking key information. The checkpoint
355   description table plays a guiding role in precise map reading. Experts and advanced beginners
356   both pay attention to the checkpoint form, but the former understands information faster and
357   are more concentrated in searching information, whereas novices pay no attention. This study
358   provides sound information for designing precise map reading training sessions for novices,
359   which may then improve their performance in competitions.

360

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Figure 1

Example of a precise map for orienteering

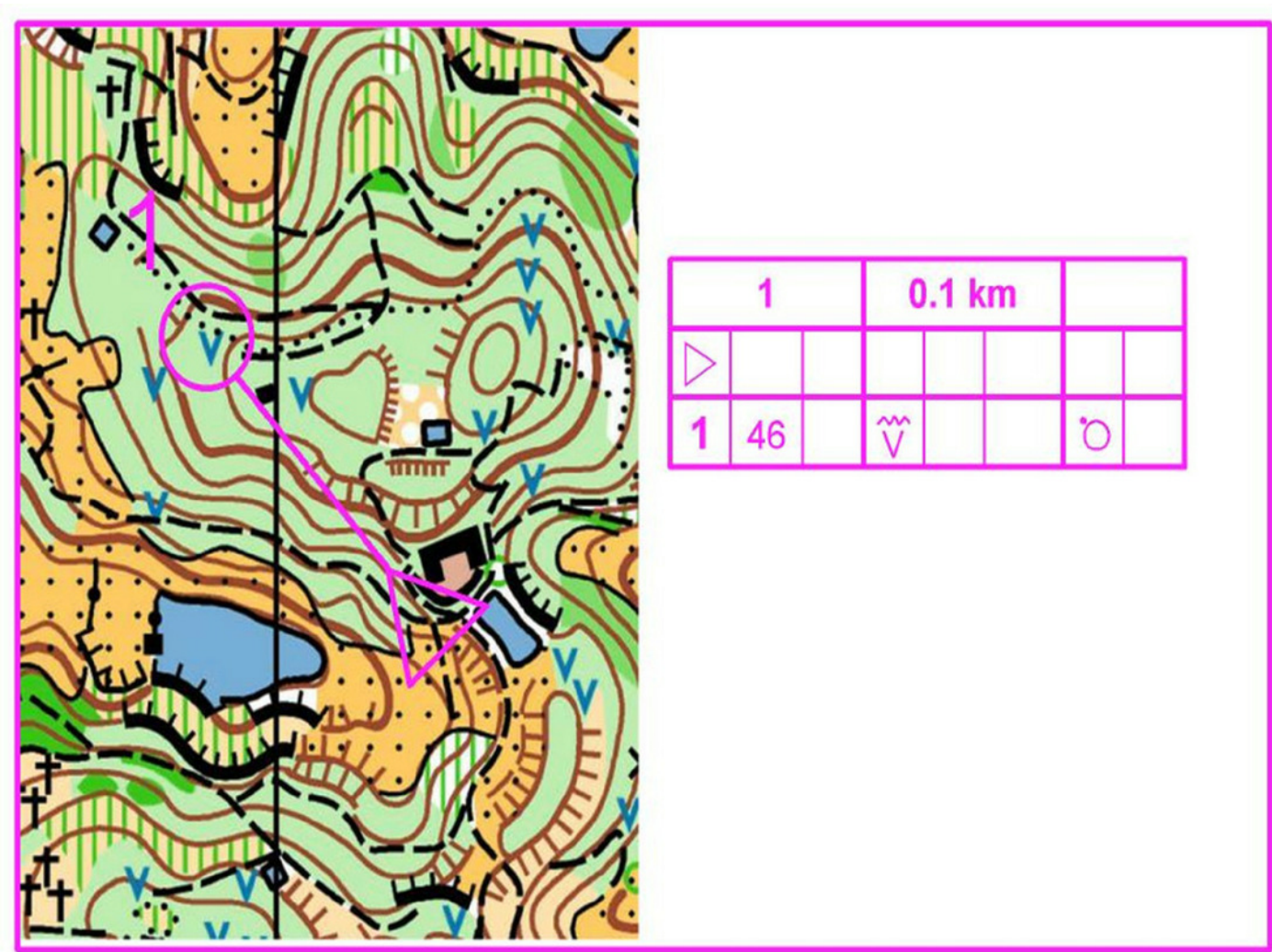



Figure 2

Flowchart for each experimental trial

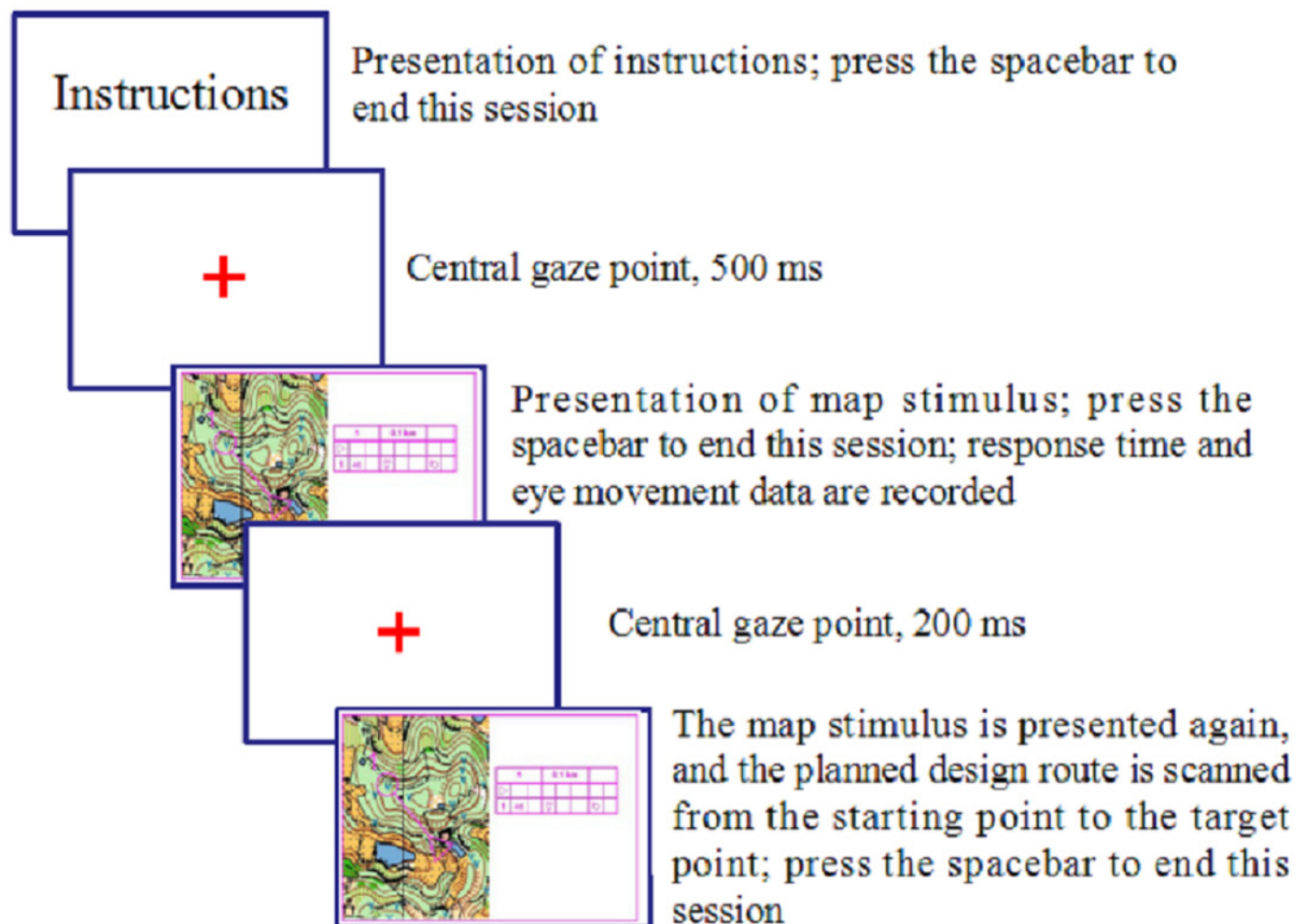



Figure 3

Comparison of route planning accuracy of orienteers at different skill levels

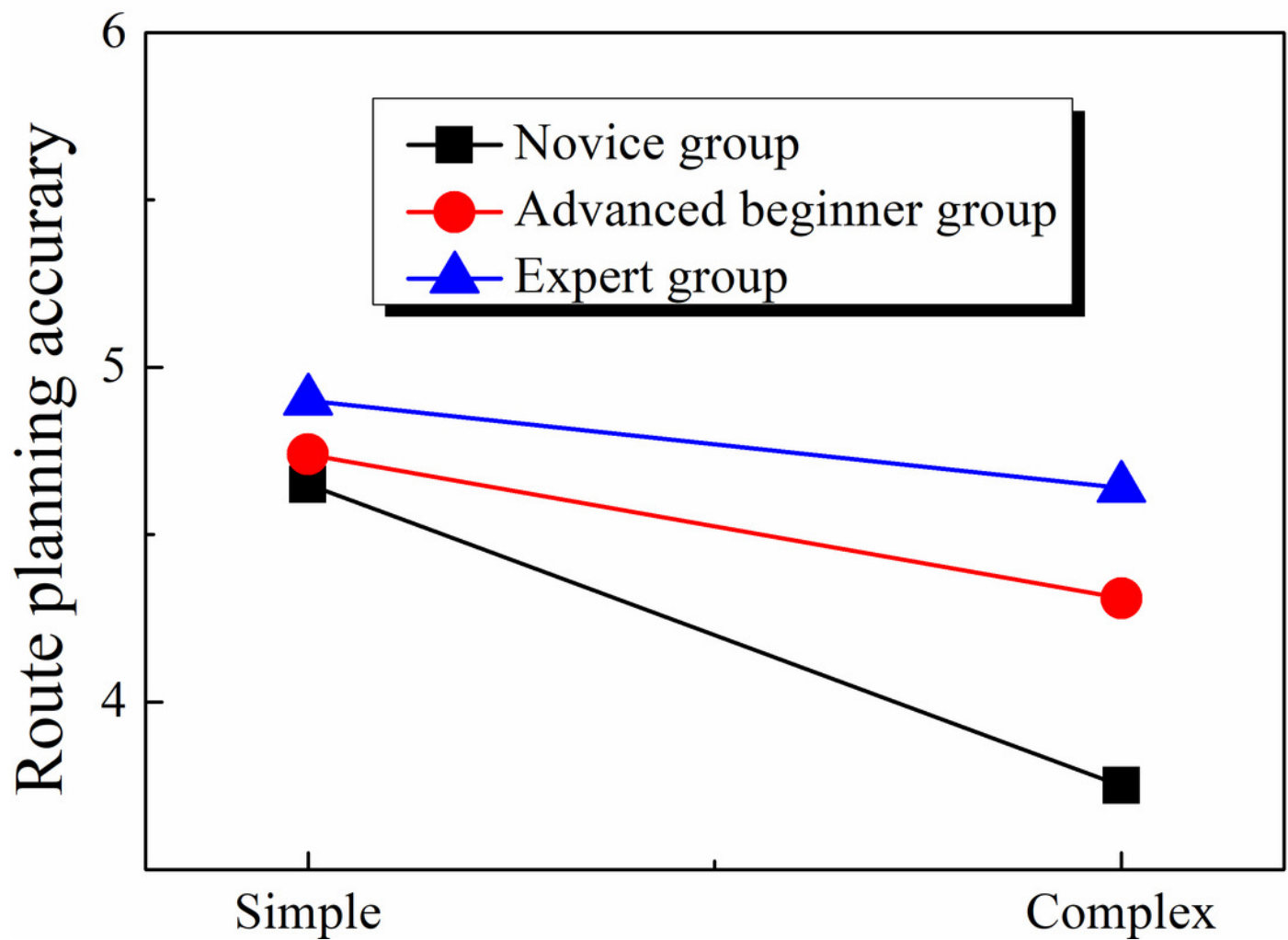



Figure 4

Comparison of route planning time of orienteers at different skill levels

Comparison_of_route_planning_time_of_orienteers_at_different_skill_levels

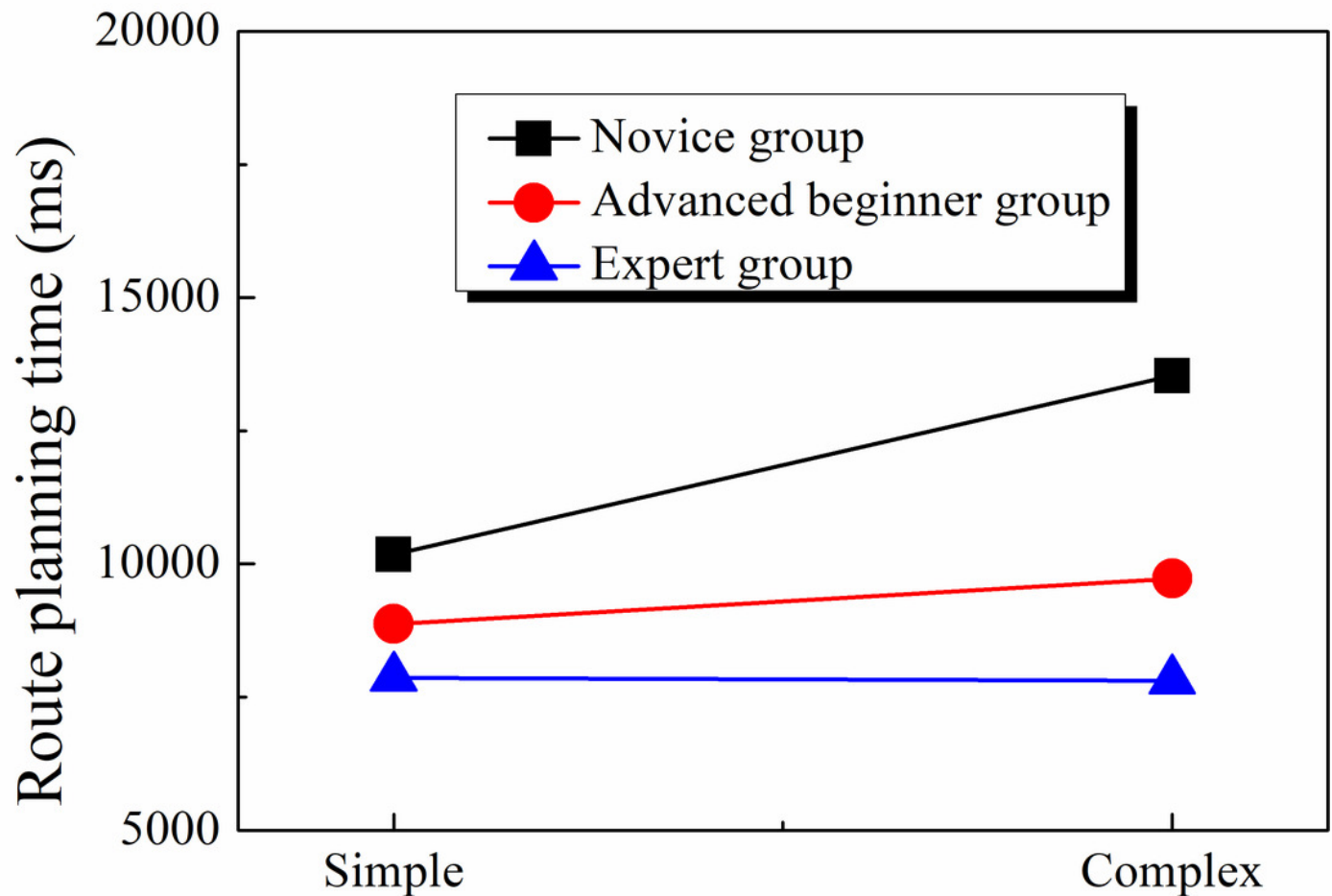



Figure 5

Gaze times of orienteers at different skill levels

Gaze_times_of_orienteers_at_different_skill_levels

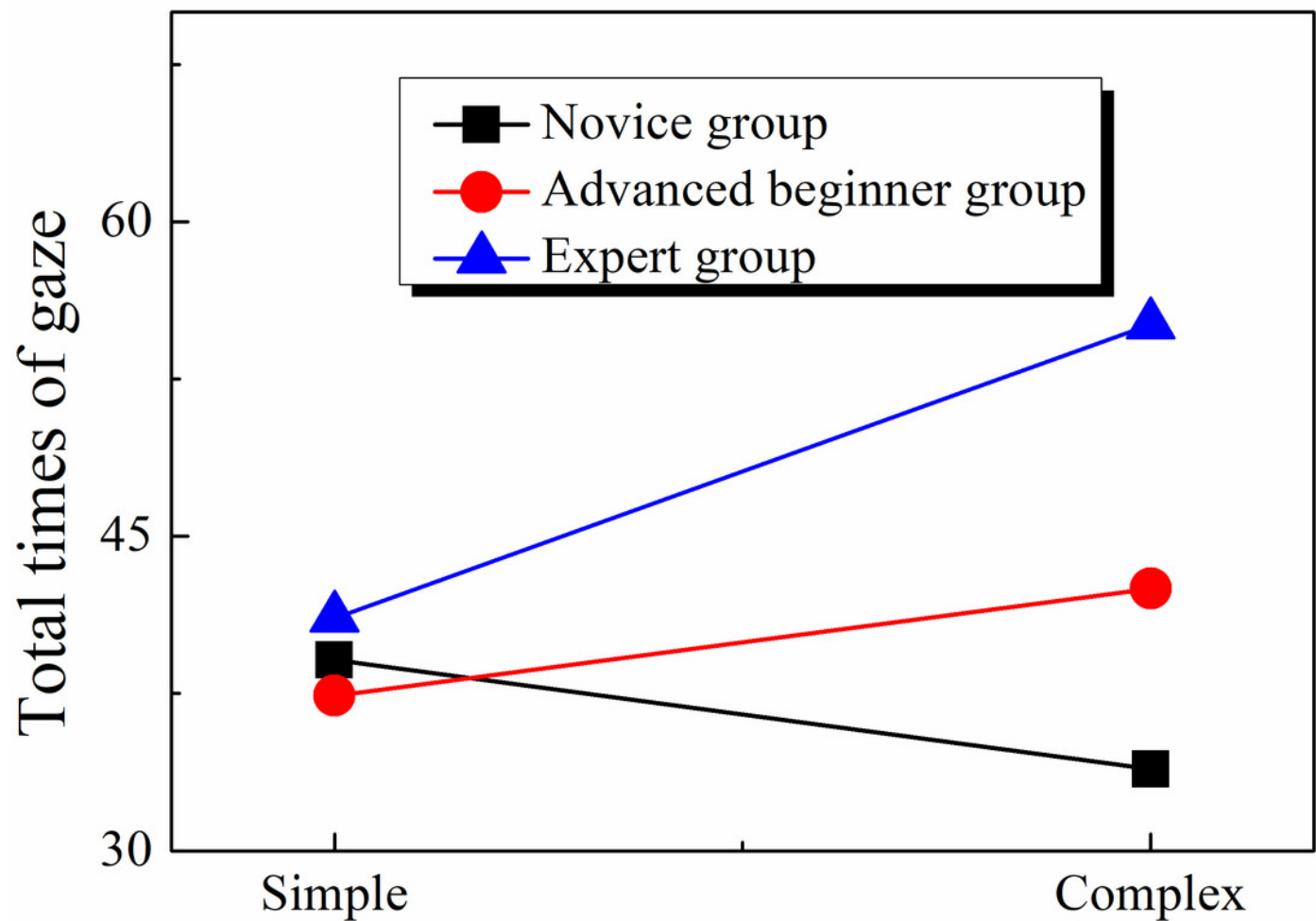



Figure 6

Gaze frequency of orienteers at different skill levels

Gaze_frequency_of_orienteers_at_different_skill_levels

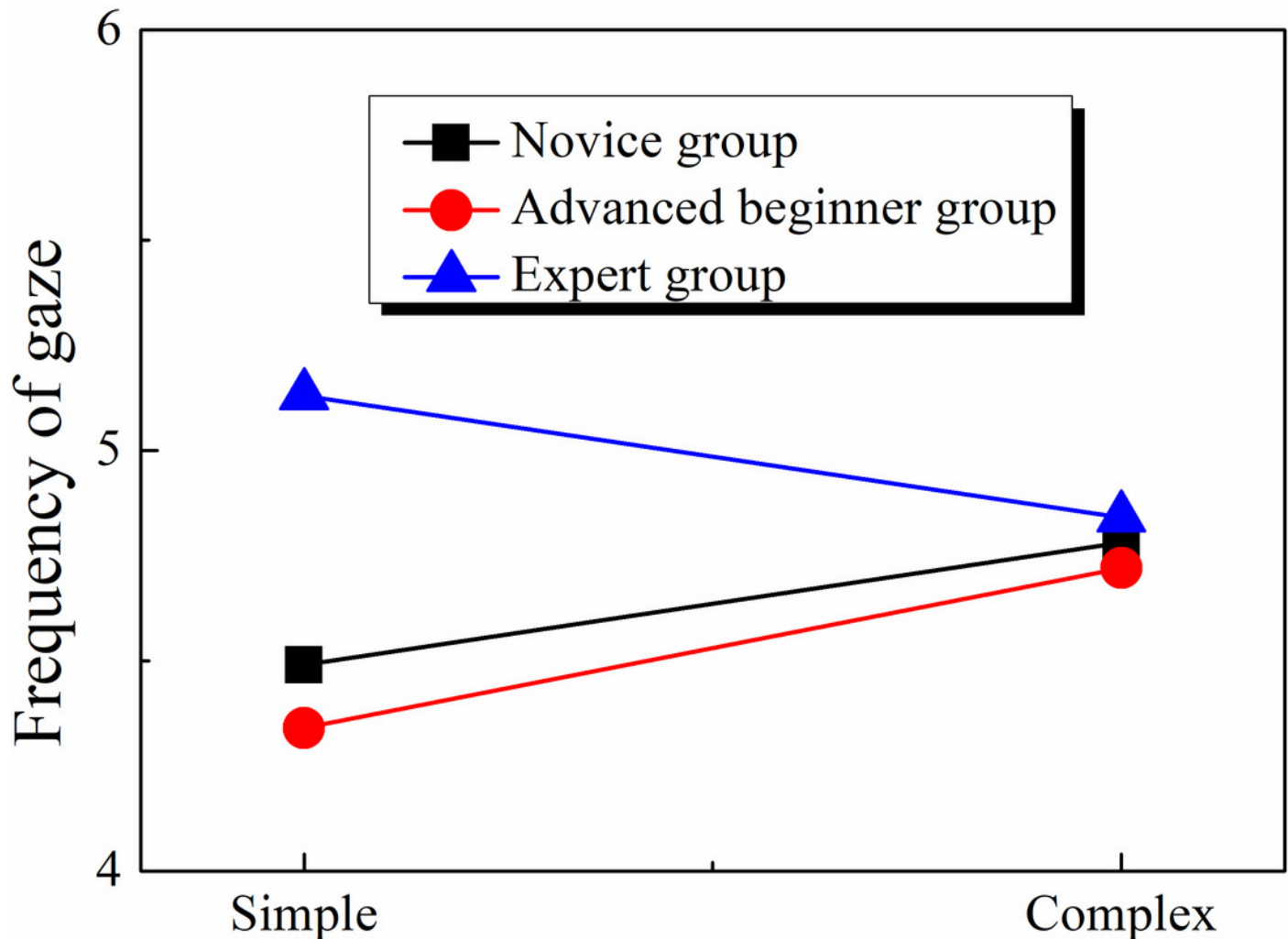



Figure 7

Movement of gaze of orienteers at different skill levels

(A) Novice group. (B) Advanced beginner group. (C) Expert group.

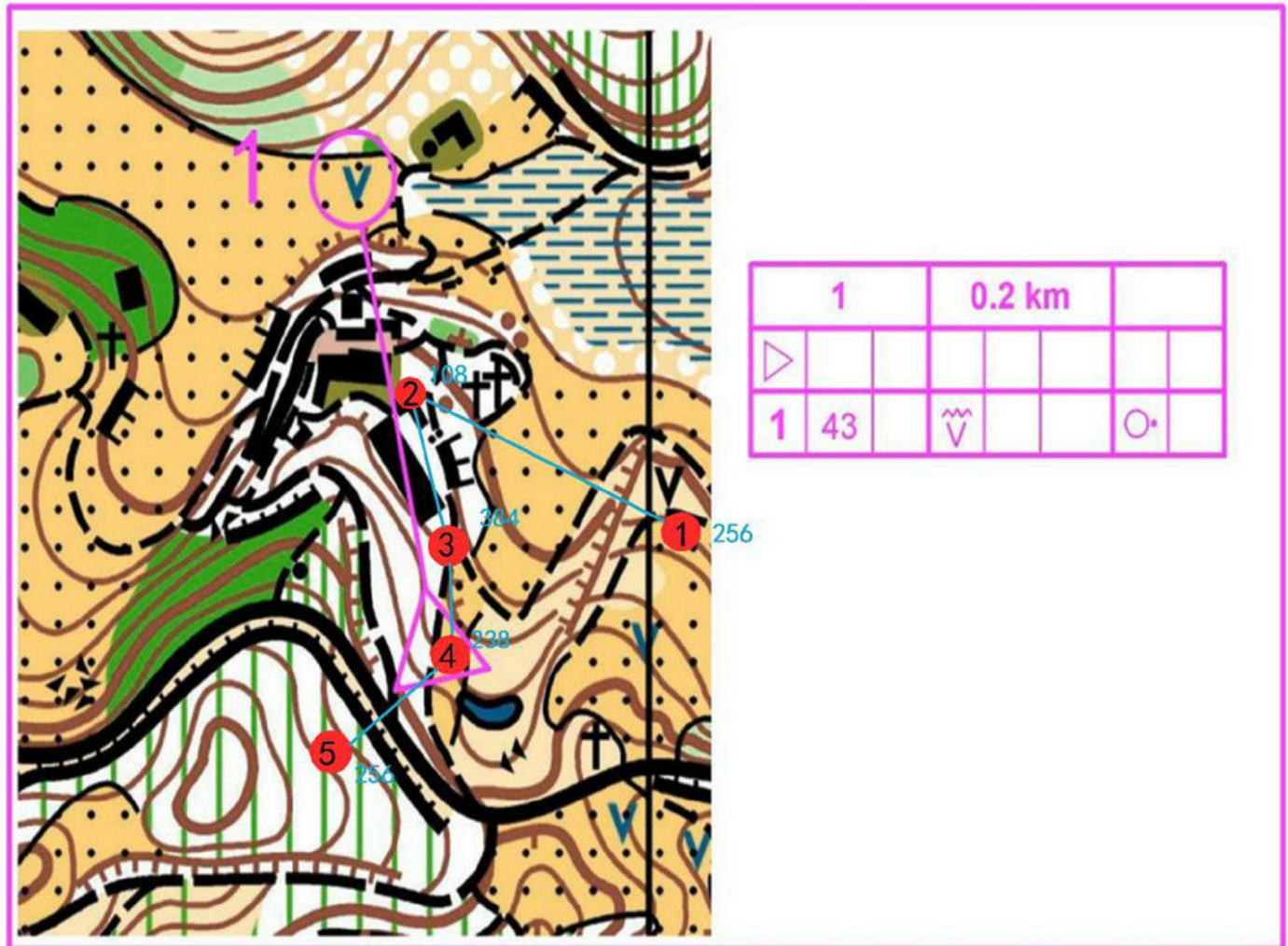
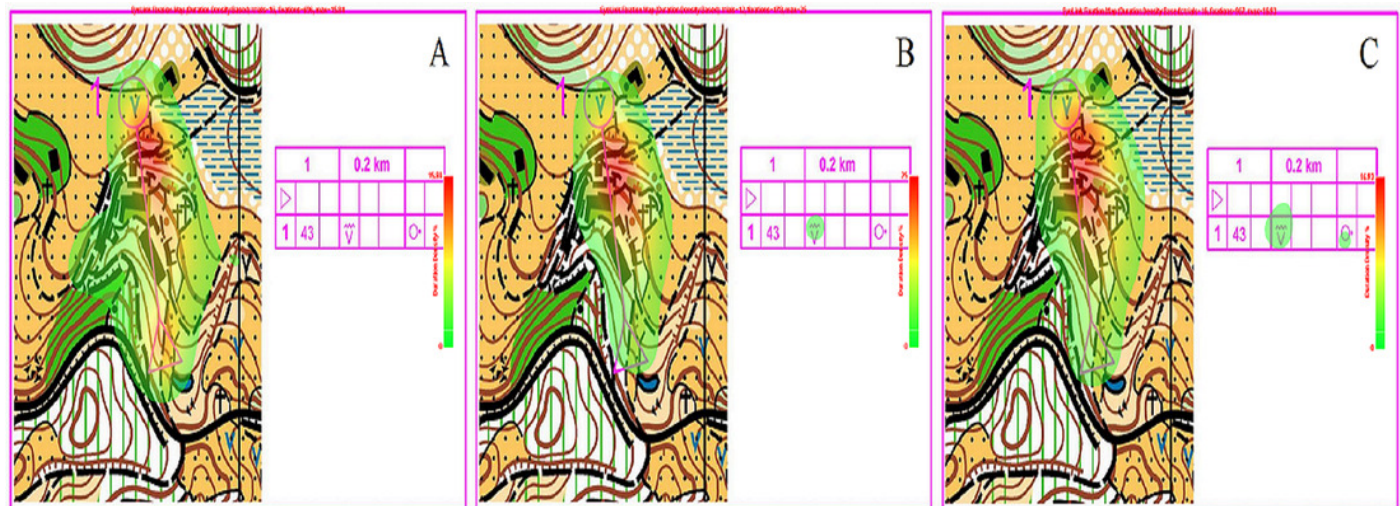



Figure 8

Fiure8

Route planning accuracy of orienteers

Skill Level	Map Complexity	Route Planning Accuracy Score	
		M	SD
Novice	Simple	4.65	0.38
	Complex	3.75	0.47
Advanced beginner	Simple	4.74	0.39
	Complex	4.31	0.36
Expert	Simple	4.90	0.29
	Complex	4.64	0.41

Route planning time of orienteers

Skill Level	Map Complexity	Planning Time (ms)	
		M	SD
Novice	Simple	10,177.65	4326.63
	Complex	13,534.0	4225.48
Advanced beginner	Simple	8870.62	1982.12
	Complex	9721.80	2985.79
Expert	Simple	7863.60	1508.87
	Complex	7808.25	2808.70

Total gaze times in route planning

Skill Level	Map Complexity	Gaze Time (ms)	
		M	SD
Novice	Simple	39.1	8.7
	Complex	33.9	4.2
Advanced beginner	Simple	37.4	9.7
	Complex	42.5	14.4
Expert	Simple	41.1	10.6
	Complex	55.1	18.4

Average gaze frequency in route planning

Skill Level	Map Complexity	Frequency of Gaze	
		M	SD
Novice	Simple	4.49	1.79
	Complex	4.78	3.12
Advanced beginner	Simple	4.34	1.41
	Complex	4.72	1.96
Expert	Simple	5.13	1.44
	Complex	4.84	1.76