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Numbers of information-processing stages and cues for determination in Kendo players with different skill levels

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In this study, the reaction times needed for kendo players with different skill levels to determine their strategies to fight an opponent displayed on a TV monitor were measured, and the numbers of information-processing stages and cues for such determination were calculated, based on the verbally reported contents of information-processing, with a view to examining the association between these numbers and skill levels. An experiment was conducted involving 8, 9, and 10 kendo players of high, intermediate, and low skill levels, respectively, and the following results were obtained:

1. There were no differences among the different skill levels in the reaction time needed for the participants to determine their own strategies or to discriminate the opponent's attack. On the other hand, the numbers of information-processing stages and cues for such determination or discrimination were higher in intermediate- than in low-level players.

2. On comparison of the values per unit (5 seconds), the numbers of both information-processing stages and cues for determination or discrimination in each trial, calculated based on the verbally reported contents of information-processing, were higher in high- and intermediate- than in low-level players.

3. The differences among players with different skill levels in the numbers of information-processing stages and cues for determination or discrimination are likely to reflect the progress of procedural knowledge elaboration and structuring.

Key words: Kendo players, expertise, procedural knowledge, reaction time, verbal report.

In many daily life settings, we communicate with others, and determine actions to be taken based

both on the information acquired through this and our own intentions. Such information acquisition is not limited to conversations with others, as we also obtain many cues from others' gazes and gestures. The level of skill to collect and select information may influence the appropriateness of subsequent actions, and this tendency is more marked in competitive sports, where fast reactions and quick decision-making are required. In this respect, analysis from the perspectives of information collection through communication with partners/opponents and information-processing ability may be helpful.

In the majority of competitive sports, the skill level markedly varies among competitors even when there are no apparent significant differences in physical strength or level of motor skill excluding situational judgment. Particularly in sports involving open skills, this tendency is marked. It has been reported that, in such sports, high skill levels are obtained by improving cognitive skills, in addition to individual motor skills such as passing and shooting, which are closely associated with information-processing, to determine appropriate strategies in a combat situation (Okumura & Yoshida, 2002).

Players' information-processing in combat situations has been frequently examined using a model created by Schmidt & Lee (2011). In this model, the process starts with the presentation of environmental stimuli, and ends with motor output after the development of 3 sub-stages: stimulus identification: analyzing collected information; response selection: determining movements to execute, based on the characteristics of the presented environmental stimuli; and response programing: organizing necessary motor systems to execute target movements. Some previous studies (Allard, Graham, & Paarsalu, 1980; Allard & Starkes, 1980; Starkes, Allard, Lindley, & O'Reilly, 1994) examining the association between the skill level and content of information-processing from such a viewpoint confirmed that players with higher skill levels have a greater ability to identify stimuli, as they more accurately determine structured situations possibly occurring in relevant sports. Such players have also been reported to be excellent in the speed with which they make appropriate judgments (Goulet, Bard, & Fleury, 1989; Abernethy, 1990) and their prediction accuracy (Kato & Fukuda, 2002; Ward, Williams, & Bennett, 2002; Zhang, Watanabe, & Mabuchi, 2008) in relevant combat situations.

The difference between high- and low-level athletes in the cognitive skill level is likely to be associated with their competition-related knowledge structure. Knowledge is classified into 2 types: declarative and procedural. While the former refers to facts, such as rules and positions, and can be described in words, the latter refers to procedures to take actions, such as passing and shooting, and cannot be described in words. In previous studies examining the relationship between the levels of these types of knowledge and situational judgment skills, it was shown that the variation in such skills among athletes is closely associated with their levels of competition-specific declarative (French & Thomas, 1987) or procedural knowledge (Thomas & Thomas, 1994). French & Thomas

(1987) also conducted a study to examine children playing basketball throughout a season, and reported that the development of specific declarative knowledge contributes to that of decision-making ability or procedural knowledge. Procedural knowledge develops through direct experiences, such as practicing, and indirect experiences, such as observing other players (Thomas & Thomas, 1994), and is considered to be maintained as an "*if* <A> occurs, *then* I do <B>" statement, based on the production rule pairing <conditions> and <actions> (French, Nevett, Spurgeon, Graham, Rink, & McPherson, 1996; McPherson, 1999; Thomas & Thomas, 1994). In high-level players, who are characterized by quickness and accuracy, as well as an ability to manage diverse situations instantaneously, information-processing may be regarded as an outcome of the development of the production rule, comprising a large number of <conditions> and <actions> closely associated with each other.

While these studies revealed differences between players with high and low skill levels, their focus was to clarify the players' knowledge structure; therefore, the participants were asked to report verbally all possible situations without time limits. In other studies examining kendo players, similarly to the present study, this method was also adopted, and it was confirmed that high-level players' knowledge is more elaborate and structured than that of low-level ones (Okumura & Yoshida, 2002). Considering the necessity of making rapid judgments and decisions within a strictly limited time frame among sportsmen and -women, it may be useful to examine their information-processing under such conditions.

In line with this, in the present study, the reaction times needed for kendo players with different skill levels to determine strategies to fight an opponent displayed on a TV monitor were measured, and the numbers of information-processing stages and cues for such determination were calculated, based on the verbally reported details of information-processing, with a view to examining the association between these numbers and skill levels.

Methods

Participants

The participants were divided into 3 groups, based on their experience of practicing kendo and their skill levels: high-level: 8 males aged 24 to 36 (mean: 29.0) and graded at 4th to 6th-*dan*, with experience of practicing kendo for 17 to 33 (mean: 23.0) years and obtaining successful results in national competitions; intermediate-level: 9 males aged 19 to 27 (mean: 23.4) and graded at 2nd to 4th-*dan*, with experience of practicing kendo for 9 to 23 (mean: 14.8) years and participating in prefectural, regional, or national competitions; and low-level: 10 males aged 22 to 30 (mean: 24.3), not graded at any *dan* level, with experience of practicing kendo for 0.5 to 1 (mean: 1.0) year without participating in any competitions. Health problems possibly interfering with this study were not

exhibited by any participant. They were provided with sufficient oral and written explanations regarding the study objective and experimental procedure to obtain their written consent to cooperate before the initiation of the experiment.

Presented images and used apparatuses

To collect images to be presented to participants during experimental sessions, combat between 2 intermediate-level kendo players (A: female, aged 20 and graded at 3rd-*dan*, with experience of practicing kendo for 15 years and who had participated in national competitions in her senior high school and university days; and B: female, aged 21 and graded at 3rd-*dan*, with experience of practicing kendo for 15 years and participating in national competitions in her senior high school days) was recorded from an appropriate angle in consideration of the participants' viewpoint, using the following apparatuses: a camera (EMR-8 VIEW CAMERA Model V-157, NAC Image Technology Inc.) was attached to Player B's fabric flaps, which was manipulated through a controller (EMR-8 CONTROLLER Model V-720, NAC Image Technology Inc.) and connected to a digital videocassette recorder (GV-D900, Sony Corporation).

The recorded combat scenes were entered into a personal computer at 30 frames per second to extract segments, each of which started when the two players standing face-to-face, and ended when A struck B. The duration of each segment was 4.2 to 18.1 (mean: 9.2) seconds.

On the basis of a program developed by the experimenter, the images were presented to the participants using a personal computer (MacBook Air Model A1466, Apple Inc.) with software (SuperLab 4.5, Cedrus Corporation) and a TV monitor (REGZA 40S5, Toshiba Co., Ltd.).

Experimental procedure

The participants were instructed to sit 1.5 m away from the front of the TV monitor, and were provided with explanations regarding the objective and method of this experiment. In addition, the following explanations were displayed on the monitor upon the initiation of the experiment:

a) This experiment aims to clarify the details of information regarding the opponent, on which kendo players' base the determination of their own strategies or those of the opponent.
b) The images you will watch during the experiment have been recorded from your viewpoint when playing kendo.
c) Observing the opponent's movements, please click the mouse as soon as you have determined your own strategies or those of the opponent.
d) After clicking the mouse, please use the IC recorder to report verbally: ① the details of your own strategies or those of the opponent that you have determined, and ② what information (movements of a part of your or the opponent's body) you have based such determination on.
e) After clicking the mouse, the relevant combat scene will be replayed; initially, a focus point

"+" will be displayed in the center of the monitor for 2 seconds and, subsequently, the relevant combat scene will be replayed.

f) The relevant combat scene will end with the opponent's strike, followed by a gray background. Even after the image has disappeared, please click the mouse as soon as you have determined your own strategies or those of the opponent.

g) After clicking the mouse, it is possible to report the above-mentioned items without time limits. Please report them in as much detail as possible.

After confirming the participants' comprehension of these explanations, a rehearsal consisting of 3 trials and the experiment consisting of 15 trials were executed. The period of time between the initiation of rehearsal and the termination of the experiment was 7 to 30 minutes (mean: 14 minutes and 13 seconds).

Data collection

Reaction time. After the initiation of a replay, the time needed for a participant to click the mouse as a signal for having determined his own strategies or those of the opponent was measured during each trial, and a mean among 15 experimental trials was adopted as that participant's reaction time.

Number of information-processing stages for determination. The number of information-processing stages needed for each participant to determine his own strategies or those of the opponent was examined based on his verbal report. Okumura & Yoshida (2002) examined kendo players "*men*" movements, and counted the following pattern as 3 stages: the player's own movement => the opponent's reaction => the player's attack. Even when the opponent did not show any movement as a reaction, or had difficulty in showing it, this pattern was similarly counted as 3 stages: the player's own movement => the opponent's reaction (no movement) => the player's attack. In the present study, the number of information-processing stages for determination was calculated, adopting this method. Although some participants' reports started from the opponent's movement, the number of stages was calculated similarly to the above-mentioned pattern, that is, starting from the player's own movement. Furthermore, there were also some participants who did not report the absence of their own or the opponent's movement; such absence of movement was also regarded as 1 stage, and a mean among 15 experimental trials was adopted as a participant's number of information-processing stages.

The numbers of these stages and below-mentioned cues for determination in each trial were quantified by 3 researchers (2 graded at 3rd-*dan* and 1 graded at 4th-*dan*, all of whom were aged 22, with experience of practicing kendo for 17 years) upon deliberations.

Number of clues in each session. The number of cues needed for each participant to determine his own strategies or those of the opponent in each trial was calculated based on his verbal report, and a mean was adopted.

Number of information-processing stages per unit (5 seconds). In order to examine the association between the number of information-processing stages within a fixed time frame and skill level, a participant's value obtained in each trial based on his verbal report was divided by the reaction time in the relevant trial to calculate the number of stages per 5 seconds, and a mean among 15 experimental trials was adopted.

Number of cues per unit (5 seconds). In order to examine the association between the number of cues within a fixed time frame and skill level, the total number of cues used by a participant before determination during each trial was divided by the reaction time in the relevant trial to calculate the number of cues per 5 seconds, and a mean among 15 experimental trials was adopted.

Statistics

Unpaired one-factor analysis of variance was performed for the following items: reaction time; and the numbers of information-processing stages, cues used in each trial, stages per 5 seconds, and cues used per 5 seconds before determination. When significant differences were observed in the main effect, multiple comparisons were performed using Bonferroni's method. For statistics, IBM SPSS Statistics 22 was used and the significance level was set at <5%.

Results

Reaction time. Figure 1 shows the mean reaction time as a period of time between the initiation of the relevant combat scene and determination for each group. The higher the skill level, the longer the reaction time, although no significant differences were observed among the 3 groups.

Number of information-processing stages. Figure 2 shows the mean number of information-processing stages and standard deviation for each group. On statistical analysis, significant differences in the main effect were observed among the groups ($F(2,24)=6.87$, $p<.01$, $\eta_p^2=.364$). Multiple comparisons revealed a significant difference between the intermediate- and low-level groups ($p<.01$).

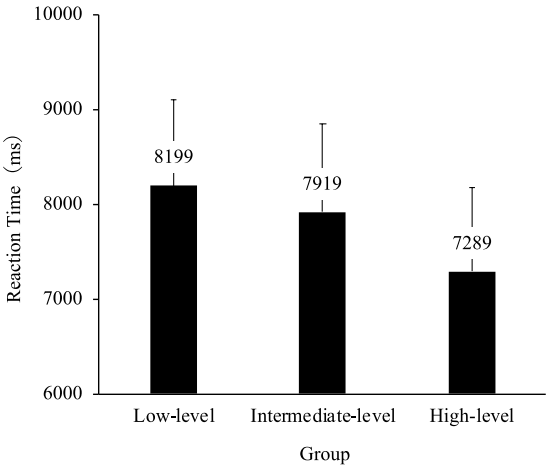

Figure 1. Mean reaction time and standard deviation for each group.

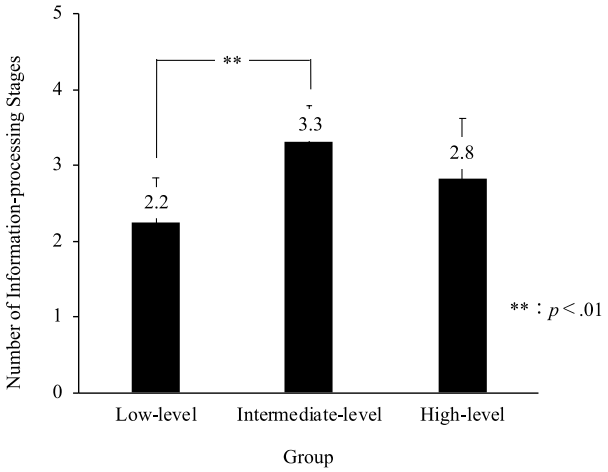

Figure 2. Mean number of information-processing stages and standard deviation for each group.

Number of cues per trial. Figure 3 shows the mean number of cues per trial and standard deviation for each group. On statistical analysis, significant differences in the main effect were observed among the groups ($F(2,24) = 7.95$, $p < .01$, $\eta_p^2 = .398$). Multiple comparisons revealed a significant difference between the intermediate- and low-level groups ($p < .01$).

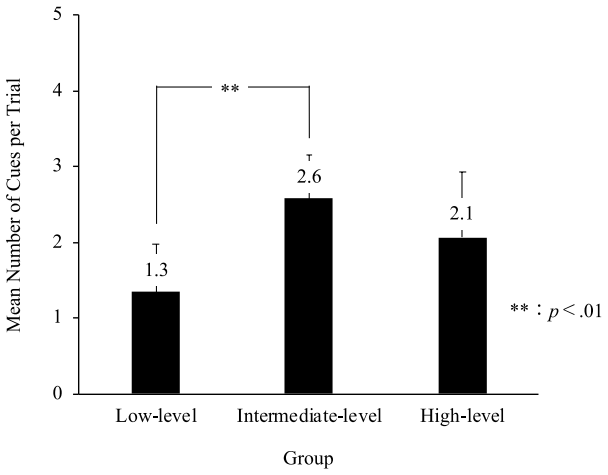

Figure 3. Mean number of cues per trial and standard deviation for each group.

Number of information-processing stages per 5 seconds. Figure 4 shows the mean number of information-processing stages per 5 seconds and standard deviation for each group. On statistical analysis, significant differences in the main effect were observed among the groups ($F(2,24)=6.24$, $p<.01$, $\eta_p^2=.342$). Multiple comparisons revealed significant differences between the high- and low- and between the intermediate- and low-level groups ($p<.05$ in both cases).

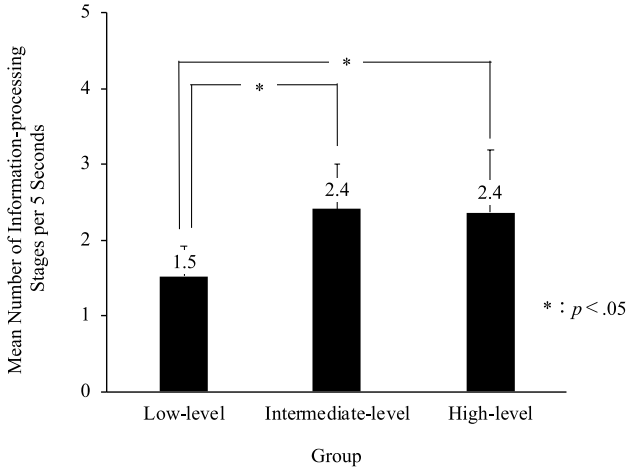

Figure 4. Mean number of information-processing stages per 5 seconds and standard deviation for each group.

Number of cues per 5 seconds before determination. Figure 5 shows the mean number of cues per 5 seconds before determination and standard deviation for each group. On statistical

analysis, significant differences in the main effect were observed among the groups ($F(2,24)=7.31$, $p<.01$, $\eta_p^2=.379$). Multiple comparisons revealed significant differences between the high- and low- ($p<.05$) and between the intermediate- and low-level groups ($p<.01$).

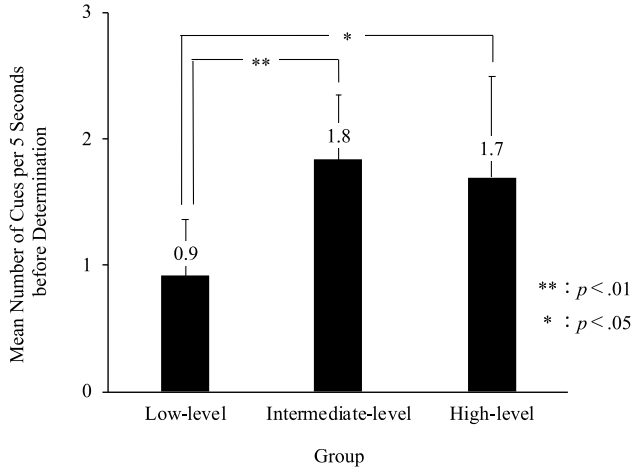

Figure 5. Mean number of cues per 5 seconds before determination and standard deviation for each group.

Discussion

In this study, the reaction times needed for kendo players with different skill levels to determine their own strategies or to discriminate the opponent's attack to fight an opponent displayed on a TV monitor were measured, and the numbers of information-processing stages and cues for such determination and discrimination were calculated, based on the verbally reported contents of information-processing, with a view to examining the association between these numbers and skill levels. No significant differences were observed among the 3 groups in terms of the reaction times needed for the participants to determine their own strategies or those of the opponent after initiation of the relevant combat scene. However, as it has been reported that the period of time between the initiation and termination of movements for attack/defense is 400 ms or less in kendo (Edo & Hoshikawa, 1984), a difference of 630 ms between the high- and intermediate-level groups and that of 910 ms between the high- and low-level groups may be regarded as representing the duration of information-processing, which influences the consequences of such movements.

Regarding the numbers of information-processing stages and cues for the determination of the participant's own strategies or the discrimination of the opponent's attack in each trial, there were significant differences between the intermediate- and low-level groups in both cases; the numbers were higher in the former than in the latter. While approximately 3 movement stages were needed,

regardless of the skill level, in the study by Okumura & Yoshida (2002), in the present study, approximately 3 and 2 stages were needed in the high/intermediate- and low-level groups, respectively. Furthermore, the mean number of cues per trial used by the intermediate-level group is larger than that of the low-level group (see Figure 3), indicating that players with low skill levels make judgments with a lower number of cues. Such inconsistency with the results of the previous study may be due to the difference in the study method. In the study by Okumura & Yoshida (2002), there were no time limits within which participants had to answer, as the study objective was to clarify their knowledge structure. In contrast, in the present study, the participants were asked to click the mouse as soon as they had determined their own strategies or had discriminated the opponent's attack after the initiation of the relevant combat scene, and verbally report the details of their information-processing during each trial. The low numbers of information-processing stages and cues in the low-level group may be explained by the influence of such time limits. This was clear in the analysis, which revealed higher numbers of information-processing stages and cues per unit in the high- and intermediate-level groups than in the low-level group.

Although the participants' procedural knowledge regarding attack or defense was possibly maintained as an "*if* <A> occurs, then I do <B>" statement, based on the production rule, the connection among time limits, <conditions> ("*if* to" statement), and <actions> ("*then* to" statement) may have been undeveloped in the low-level group, resulting in the insufficient elaboration and structuring of procedural knowledge and difficulty in accurately recognizing the details of <conditions> ("*if* to" statement). In other words, low-level group members may have faced difficulty in scanning the game situations during the stimulus identification stage. Such difficulty may negatively influence the selection of effective responses in relevant combat scenes, and motor output as an outcome of such information-processing is likely to be inappropriate. Similarly, in the same combat scene, those with undeveloped procedural knowledge are likely to need more time to process information than those with developed procedural knowledge; this should be overcome in sports such as kendo where temporal restrictions are severe. In such cases, although efforts are made to shorten the time needed for information-processing to select effective responses, due to insufficient elaboration and structuring of procedural knowledge, it is necessary to make situational judgments through a lower number of information-processing stages using fewer cues, which is considered to have been reflected in low skill level of low-level group members.

On the other hand, upon comparison between the high- and intermediate-level groups showing a clear difference in the skill level, the numbers of information-processing stages and cues were higher in the latter than in the former, although the differences were not significant. This suggests that intermediate-level players may make judgments with a higher number of cues. In addition, considering the above-mentioned characteristics of kendo, the difference in the reaction time between the high- and intermediate-level groups is likely to reflect the difference in the number of

information-processing stages or cues. Although the differences between the high- and intermediate-level groups in these items were not significant, the long-term experience of practicing kendo may have promoted procedural knowledge elaboration and structuring in the former. In this respect, the difference in the skill level between them may be explained by the degree of elaborating and structuring of knowledge retained.

In short, as Okumura & Yoshida (2002) also noted, kendo players' skill levels may be influenced by the retention of diverse procedural knowledge, in which <conditions> and <actions> are closely associated with each other. On the other hand, differences among the 3 groups, such as those in the reaction time, were not significant in the present study, presumably due to the difficulty inserting the context of the kendo scene, which is the interaction with opponent up to the scene presented in the experiment. Further studies may be necessary to confirm findings from the study in consideration of this issue.

References

Abernethy, B. (1990). Expertise, visual search, and information pick-up in squash. *Perception*, **19**, 63-77.

Allard, F., Graham, S., & Paarsalu, M. E. (1980). Perception in sport: Basketball. *Journal of Sport Psychology*, **2**, 14-21.

Allard, F., & Starkes, J. L. (1980). Perception in sport: Volleyball. *Journal of Sport Psychology*, **2**, 22-33.

Edo, K., & Hoshikawa, T. (1984). A time analysis of kendo defense. *Research Journal of BUDO*, **16(3)**, 31-39.

French, K. E., & Thomas, J. R. (1987). The relation of knowledge development to children's basketball performance. *Journal of Sport Psychology*, **9**, 15-32.

French, K. E., Nevett, M. E., Spurgeon, J. H., Graham, K. C., Rink, J. E., & McPherson, S. L. (1996). Knowledge representation and problem solution in expert and novice youth baseball players. *Research Quarterly for Exercise and Sport*, **67(4)**, 386-395.

Goulet, C., Bard, C., & Fleury, M. (1989). Expertise differences in preparing to return a tennis serve: A visual information processing approach. *Journal of Sport and Exercise Psychology*, **11**, 382-398.

Kato, T., & Fukuda, T. (2002). Visual strategies of baseball batters during the preparatory phase of batting. *The Japanese Journal of Ergonomics*, **38(6)**, 333-340. (In Japanese with English abstract.)

McPherson, S. L. (1999). Expert-novice differences in performance skills and problem representations of youth and adults during tennis competition. *Research Quarterly for Exercise*

and Sport, **70(3)**, 233-251.

Okumura, M., & Yoshida, S. (2002). Knowledge structure of offensive action pattern in varsity kendo players. *Japanese Journal of Sport Psychology*, **29(1)**, 30-40. (In Japanese with English abstract.)

Schmidt, R. A., & Lee, T. D. (2011). *Motor control and learning: A behavioral emphasis* (pp.57-95). Champaign, IL: Human Kinetics.

Starkes, J., Allard, F., Lindley, S., & O'Reilly, K. (1994). Abilities and skill in basketball. *International Journal of Sport Psychology*, **25**, 249-265.

Thomas, K. T., & Thomas, J. R. (1994). Development expertise in sport: The relation of knowledge and performance. *International Journal of Sport Psychology*, **25**, 295-312.

Ward, P., Williams, A. M., & Bennett, S. J. (2002). Visual search and biological motion perception in tennis. *Research Quarterly for Exercise and Sport*, **73(1)**, 107-112.

Zhang, J., Watanabe, K., & Mabuchi, M. (2008). A study on anticipatory accuracy and visual search strategy of skilled and novice soccer players: Compared between 1 vs. 1 and 3 vs. 3 situations. *Japan Journal of Physical Education, Health and Sport Sciences*, **53**, 29-37. (In Japanese with English abstract.)

熟練度の異なる剣道選手の意思決定における情報処理の段階数と手がかり情報数

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本研究の目的は、熟練度の異なる剣道選手を対象として、テレビモニタに映し出される対戦相手への対応を決定するまでの反応時間を測定するとともに、この決定に至るまでの情報処理内容の口述から対応決定までの情報処理の段階数と利用した手がかり情報数を導出し、これらと選手の熟練度との関連について検討することであった。上級者群 8 名、中級者群 9 名、初級者群 10 名を対象に実験を行い、以下の内容が明らかになった。

1. 問題場面の再生開始から実験参加者が実行する攻撃の決定、あるいは、対戦相手が仕掛けてくる攻撃の判別までの反応時間には熟練度による差異は認められなかった。一方で、この決定あるいは判別に至るまでの情報処理の段階数及び利用した手がかり情報数は、いずれも初級者群に比べ中級者群が多かった。

2. 実験参加者の口述内容から得られた各試行における決定あるいは判別までの段階数及び手がかり情報数について、単位時間（5 秒間）あたりの数値を算出し比較したところ、初級者群に比べ上級者群及び中級者群のほうが段階数・手がかり情報数ともに多かった。

3. 決定あるいは判別までの段階数及び利用した手がかり情報数にみられた群間の差異は、手続き的知識の精緻化・構造化の進度を反映していると推測された。

キーワード：剣道選手、熟練度、手続き的知識、反応時間、言語報告