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Computer-assisted expertise and error prediction in martial arts sequences for targeted training: Insights from a workshop

Benjamin Strenge
Ludwig Vogel
& Thomas Schack

Abstract

Athletes' expertise and likelihood of errors in action sequences like choreographed movement patterns in kata are associated with properties of their mental representation structures, which can be assessed with measurement and analysis tools based on structural-dimensional analysis of mental representations. Individual performance predictions could then facilitate coaching, deliberate practice, and targeted training. We conducted an application-oriented scientific workshop that explained the cognitive theory, requirements and limitations of the methodology, and demonstrated the QSplit SDA-M Suite as a software tool for data acquisition, individual and group-related assessments. The workshop allowed an interactive, collaborative usage of the tool to gain familiarity and personal experience with these approaches by encouraging participants to define a martial arts action sequence and retrieve their mental representation structure of that sequence. Comments and questions raised in the workshop context were concerned with the definition of "errors" in kata, interactions of multiple people, the influence of camera angle on visual representations of basic action concepts, and the atomicity of associated movements, pointing to new applications and alternative interpretations of results.

karate, kata, performance, SDA-M, mental representations, deliberate practice

Kontakt

Dr. Benjamin Strenge
Bielefeld University
benjamin.strenge@uni-bielefeld.de

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1 Introduction

The goal-directed planning and execution of human activities is based on mental representations of actions and influenced by their structuring. Analogously to object concepts in psychology, these cognitive units of human action have been described as *basic action concepts* (BACs; Schack & Mechsner, 2006), which serve as problem-solving operators available to a specific person or group of persons. The significance of BACs for human performance has been investigated with respect to complex movements in sports (e.g. Bläsing et al., 2009), tactics (Lex et al., 2015; Vogel & Schack, 2023), manual action (Stöckel et al., 2012), rehabilitation (Braun et al., 2007; Jacksteit et al., 2017) and even technical domains like cognitive robotics (Schack & Ritter, 2009, 2013).

The connections and strengths of association between BACs in a person's long-term memory can be measured with the *structural-dimensional analysis of mental representations* method (SDA-M; Schack, 2012). To this end, SDA-M software tools like the *QSplit SDA-M Suite for Windows* employ a special semi-automatized survey, the so-called *split procedure*, during which random pairs of potential BACs for a given activity are presented in textual and pictorial form and respondents must state whether they believe that these BACs are directly associated to each other during action execution (Figure 1).

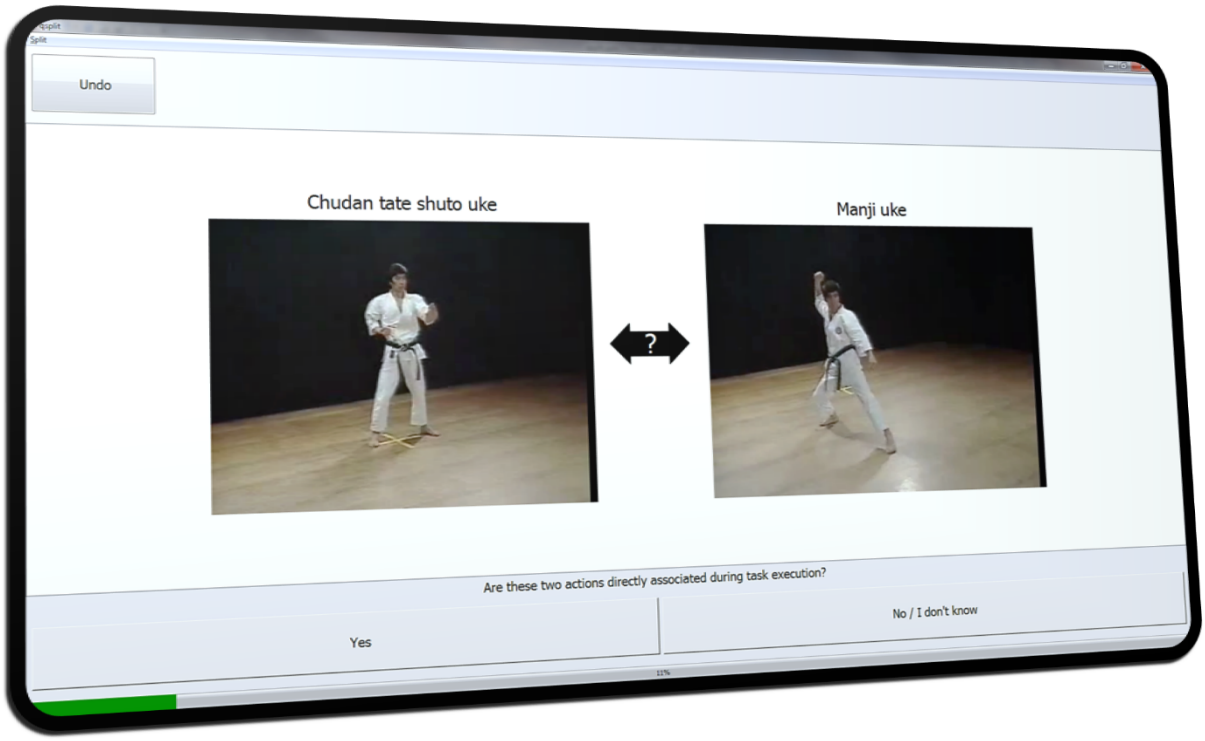

Figure 1: *Screenshot of the QSplit SDA-M Suite during a split procedure for the Kanku-dai kata (reprinted from Strenge et al., 2020).*

The data retrieved from this split procedure is then further analyzed, for example with the *correct action selection probability analysis* (CASPA) algorithm, to predict the individual expertise and likelihood of human error in a given action sequence (Strenge et al., 2019; see Figure 2).

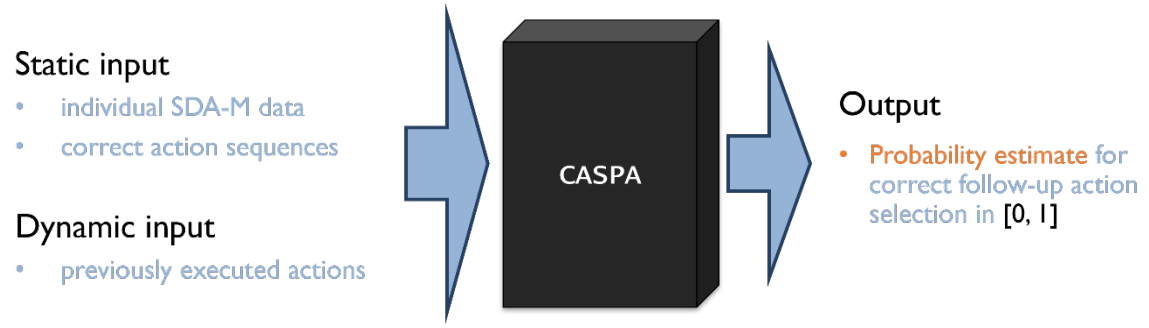

Figure 2: *Input and output signature of the SDA-M-based CASPA algorithm*

In Japanese martial arts like karate, choreographed action sequences of central importance are called *kata*, which can be described as "formal patterns of movements in which Karate stances, techniques, and moves are preserved and passed on" (P. Kuhn in Abernethy et al., 2019, p. 2). Compared to other common elements of karate training, namely *kihon* (basics) and *kumite* (rule bound fighting), "kata have a long(er) history" (Kretschmer, 2020, p. 1). While they are nowadays commonly practiced and performed merely as a physical exercise or demonstration with a focus on aesthetic considerations, karate masters Iain Abernethy and Jesse Enkamp discussed that kata were originally created as "a record of a solution to civilian conflict" that serves "as a memory aid" for self-defense applications (Abernethy et al., 2019, p. 10). However, being interpreted by individual practitioners, kata has been considered as one of karate's most fascinating aspects (Meyer & Bittmann, 2019).

Previous research had shown that karate practitioners' likelihood of choosing correct techniques in an action sequence from the Kanku-dai kata could be predicted based on automatized analyses of their mental representation structures with SDA-M and CASPA to determine their task-related expertise (Strenge et al., 2020). These results could be used to inform and guide subsequent individually tailored training and deliberate practice, either practically or through action observation (see also Petri et al., 2019) and mental imagery. However, open questions remain concerning the scope of applicability of these approaches to other types of action sequences in various martial arts and combat sports, as well as regarding the entailed practical challenges. Therefore, a workshop at the *11th Annual Conference of the dvs-Commission on Martial Arts and Combat Sports* "*Psychology in Martial Arts and Combat Sports*", which took place at the University of Bayreuth from 2024-03-13 to 2024-03-15, aimed to provide an overview of the methodology's current state and explore further applications and practical limitations.

2 Workshop Structure

About two weeks before the actual workshop was conducted, all participants were invited to download the QSplit SDA-M Suite software tool for non-commercial scientific and research purposes free of charge and asked to brainstorm in advance about potential sequences of actions (martial arts techniques) that they would like to investigate that satisfy the following criteria:

- *Atomicity*: Each action is self-contained insofar as it is assumed to be executable without issues.
- *Sequential discreteness*: Actions should not overlap in time. A correct sequence of actions can be formed by strictly ordering (a subset of) all actions.
- *Non-recurrence*: Each action appears at most once in the sequence (or can unambiguously be distinguished by adding sequential information, like "*First roundhouse kick*", "*Second roundhouse kick*", etc.).

The application-oriented scientific workshop then consisted of three parts:

1) a talk about the current state of the related science and technology, i.e., the theoretical background and methodology underlying SDA-M (Schack, 2012), the assumptions and prerequisites of the CASPA algorithm (Strenge et al., 2019), and results from previous empirical research concerning karate kata (Strenge et al., 2020),
2) a practical live demonstration of the QSplit SDA-M Suite including the execution of a split procedure with a workshop participant,
3) and the moderated discussion about potential limitations and applications with workshop participants.

The diverse group of participants consisted of scientists, researchers, and practitioners of martial arts and combat sports and included high-level experts, coaches, and masters of various styles such as karate, judo, boxing, kickboxing, kobudo, kung fu, iaido, capoeira, and Brazilian jiu-jitsu.

3 Results and Discussion

The comments and questions raised in the context of the workshop were mainly related to the following issues:

The definition and nature of "errors" in kata

In the study by Strenge et al. (2020) any instance of action selection that was not in line with the predetermined kata sequence (or failure to choose and execute any action at all) was considered erroneous. For example, if the original kata sequence contained a *mae geri* (front kick) but a participant executed a *mawashi geri* (roundhouse kick) instead, this would have been counted as an error. This appears to be in line with judgments in modern kata competitions. It could be argued though that such deviations from the prescribed standard techniques of a kata are not actually "errors" but rather justifiable alternatives depending on the specific context of the application. From a pragmatic self-defense perspective and for the primordial purpose of kata as discussed above, this attitude makes perfect sense. However, it has also been argued that kata encodes information about "the physical side of self-protection in a logical, structured, and highly effective way" (Abernethy et al., 2019, p. 11). The relevant information for handling a given situation may then be found on different layers of abstraction within the kata and its elements, so arbitrarily switching techniques for other techniques may under-

mine the conveyance of that content. All in all, considering technical deviations within a predetermined kata as "errors" appears appropriate in the context of teaching and learning a traditional kata as it was recorded, but karate teachers should take care to clarify to their students that numerous alternative action selections and sequences can certainly be just as viable and appropriate in a given context.

Interactions between multiple people

While large parts of today's karate training, except kumite, mostly consist of actions executed by a single practitioner in isolation, other martial arts and especially combat sports focus more on the interaction between two or more people (e.g. opponents in a fight). So far, little research has been conducted on how such interactions could be represented and considered in the framework for analyzing the corresponding mental representation structures. In principle, this should be possible if and only if the set of possible or probable interactions is strictly limited (e.g. as in the rather deterministic *kihon kumite*), but further research is needed to draw any reliable conclusions.

Atomicity of associated movements

Another question was how respondents should decide in the split procedure if two movements are so strongly associated that during execution and application, they merge and form a single coherent technique, such as the *choku tsuki* (straight punch) and *uchi uke* (outward block) in the opening sequences of the *bassai-dai* and *kanku-dai* kata, which are executed in rapid succession. Usually, both "parts" of these techniques would be considered as BACs, if they could also be executed in isolation, and respondents should declare them as associated with each other in the split procedure, but this depends on the practitioner's expertise and other factors. In any case, it can be shown that the mathematical approaches that are applied during the analysis phases of SDA-M and CASPA are actually quite robust against this type of possible minor inconsistencies in respondents' decisions about pairwise associations between basic actions in most practical applications.

Influence of camera angle of BAC pictures

Lastly, the role of the perspective, in which the photos of the BACs were taken, was discussed (i.e., first person or third person, from the back or front). In general, this is important insofar as respondents must be capable of effortlessly and unambiguously associating the pictorial representation of a BAC with the respective cognitive unit in their memory. Any "archetypical" representation that enables a clear recognition of the encoded action works well for this purpose. In karate, third-person pictures from the front usually seem most suitable according to this criterion; however, in that case, the respondents will commonly need to perform mental rotations and possibly other related types of cognitive operations to access the action representation, which may lead to longer response times during the split procedure and other issues.

4 Outlook

Generally, the analysis of mental representation structures in martial arts and combat sports is still a largely untapped territory with great potential to improve individualized training. Based on the insights gained in the context of this workshop, any strictly defined, limited, and deterministic action sequence from martial arts appears most suitable for these approaches. Future research might explore potential

applications in more “open” scenarios such as those involving different possible reactions and multiple combatants.

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