The Think Aloud Method: What Is It and How Do I Use It?

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Abstract

This paper describes the nature and utility of the think aloud method proposed by Ericsson and Simon (1993), a method for studying thinking that qualitative researchers from any disciplinary background can consider as an option for understanding thought. The paper begins with an overview of the theoretical framework underpinning the think aloud method, and how this framework is proposed to address shortcomings of traditional interview-based methods of understanding participants' thinking. It continues with a description of a study using the think aloud method of golfers' thoughts during putting (Arsal, Eccles, & Ericsson, 2016) with the aim of demonstrating how the method can be applied, and as an opportunity to present examples of thoughts and explore how these thoughts function in the control of putting tasks. The paper finishes with proposals for how qualitative researchers might integrate the think aloud method into their own research on sport, exercise, and health, and a discussion of common pitfalls and concerns with applying the method.

Keywords: cognition; mobile interviews; process tracing; protocol analysis; thinking; verbal reports

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How do athletes perceive their bodies (Bennett, Scarlett, Clarke, & Crocker, 2016), what are mentally tough exercisers thinking in exercise settings (Crust, Swann, Allen-Collinson, Breckon, & Weinberg, 2014), and what are "dominant thoughts" of sports fans about their commitment to their sport (Hall, Shearer, Thomson, Roderique-Davies, Mayer, & Hall, 2012). These are some of the questions asked in recent studies published in this journal. These questions share a goal, which is to obtain insights into participants' thoughts, where the premise is that these insights affords a better understanding of the topic. The objective of this paper is to present a method of understanding thinking about which the qualitative researcher may have given less consideration as an option for understanding thought. This is the think aloud method proposed within mainstream psychology by Ericsson and Simon (1993).

Within the think aloud method, participants think out aloud while performing a given task, or recall thoughts immediately following completion of that task. A typical verbalized thought stream might look as follows, where the task here is a golf putt: "Get my line, more to the left, and putt". The theory underlying this method proposes that thoughts elicited by the method are a valid reflection of at least a subset of the thoughts involved in the mediation of the task being performed. We ask the reader to consider that this method involves qualitative data and yet, we believe, is overlooked by qualitative researchers, including those of sport, exercise, and health. Consequently, we highlight here how this method might contribute to the suite of methods available to qualitative researchers of all ontological and epistemological positions. In addition, some early attempts to import the method into the sport, exercise, and health arenas have resulted in its misapplication (see Arsal, Eccles, & Ericsson, 2016), and so we provide here general guidance for, and an example of the appropriate application of the method.

Our presentation of the think aloud method will hopefully stimulate thought and discussion. Eyebrows may be raised in response to the origins of the think aloud method, which are in experimental psychology, arguably a field perceived as antithetical to qualitative research. The cognitivist underpinnings of the method, where the individual is metaphorized as an information-processing machine, also may lead to some uncomfortable shuffling by the reader. Running through our arguments here is a representational view of language that assumes that elicited verbal reports can afford a veridical reflection of cognitions. By contrast, many qualitative researchers consider that language is constitutive and the meaning of words is relationally and socially constructed (Cosh, LeCouteur, Crabb, & Kettler, 2013; McGannon & Spence, 2010), whereas the "cold machines" of cognitivism do not socialize. Finally, reactions also will be provoked by the ontological and epistemological basis of the method, which is positivist and empiricist, and by assertions that thoughts elicited via the method afford a more valid reflection of participants' thoughts than do interview methods. However, we are confident that qualitative researchers holding constitutive views of language and adopting relativist and constructionist positions can still use the think aloud method and see their research benefit from it. When underpinned by these theoretical and philosophical positions, the verbal reports elicited by the think aloud method would not be assumed as valid and objective, providing the final truth, and to simply mirror cognitions. From these positions, the results of the method would be different from, and not better or worse than, those obtained by alternative methods of studying thinking. In sum, we are optimistic that the method offers opportunities to understand thinking of interest to qualitative researchers of all theoretical and philosophical colours.

Our showcasing here of the think aloud method as a useful option for understanding thinking does not mean that we are blind to the shortcomings of studies employing this method. A key omission from such studies within the sport, exercise, and health arenas is any

evidence of the thoughts themselves! Within these studies, thought data are "quickly" coded and quantified, and with the goal of hypothesis testing, consistent with the traditions of experimental psychology. Nonetheless, the usual result is that participants' thoughts only ever appear as briefly as possible to demonstrate how thoughts were coded. This is certainly true for our own research on skilled athletes (e.g., Arsal et al., 2016, Calmeiro, Tenenbaum, & Eccles, 2010, 2014; McRobert, Ward, Eccles, & Williams, 2011), where the reader will obtain few insights into what athletes' thoughts look like and find little exploration of how these thoughts function to control the athletes' sport tasks. However, qualitative research has quite different goals to those of experimental psychology, which provides us here with an opportunity to present some examples of thoughts elicited via the think aloud method and explore their function in a little more detail. Specifically, we examine thoughts verbalized by golfers of different skill levels as they perform putts of differing difficulty to understand how these thoughts function to control putt preparation and execution. Providing this window to participants' thoughts, which is rare in studies of sport, exercise, and health, will be of interest and utility to the community of researchers working in these arenas.

We begin with an overview of the theoretical framework underpinning the think aloud method, and how this framework is proposed to address shortcomings of traditional interview-based methods of understanding thinking. We then describe a study using the method of golfers' thoughts during putting, to showcase the application of the method and examples of elicited thoughts and their functions. We finish by suggesting how the think aloud method might be integrated with more traditional qualitative research methods and flagging common pitfalls and concerns with applying the think aloud method.

Theoretical Background to the Think Aloud Method

Concerns over the validity of self-reports of thinking have a long history, and a review of this history is beyond the scope of this paper (see Ericsson, 2006). Here, the focus is on the contemporary debate in psychology, and revolves around two papers (Ericsson & Simon, 1980; Nisbett and Wilson, 1977) influential in this debate (see also Eccles, 2012).

Telling More Than We Can Know; Nisbett and Wilson's (1977) Review

Nisbett and Wilson's (1977) review of research in social psychology led them to propose that people often provide inaccurate reports about their cognitions because they have limited conscious access to them. When an individual is asked to report on their cognitions but is unable to access them, he or she often accesses implicit theories about these cognitions, which are fundamental assumptions about how the world generally works, to provide the report. The problem with implicit theories is that they are often unrelated to the individual's actual cognitions.

An example of research reviewed by Nisbett and Wilson that demonstrates this problem includes Maier's (1931) classic studies of problem solving. In one problem, two cords were hung from a laboratory ceiling, and the problem was to tie the ends of the two cords together. As the participant discovered, the cords were far enough apart that it was impossible while holding one cord to reach the end of the other. Maier was interested in one particular solution to this problem of tying an object to the end of one of the cords and then swinging the cord as pendulum so that it would pass near the other cord, whereupon both cord ends could be grasped and tied. If this solution was not discovered within 10 minutes, Maier provided hints about the solution to the participants. One hint involved an experimenter "accidentally" brushing one cord while walking about laboratory so that the cord swung slightly. Despite the 10 minutes provided to discover the pendulum solution before the hint, all 16 participants in Maier's study needed the hint to discover the solution,

which was discovered an average of 42 s following the hint. However, when the participants were asked how they discovered the solution, only 1 from 16 made reference to the hint. The remainder offered a variety of explanations, such as “It was the only thing left”. When specifically asked whether they had seen the hint, 11 participants suggested that they were unaware of it but could understand how it could have been useful in eliciting their solution discovery and the remaining 4 were sure the hint played no role in their solution discovery.

Maier (1931) used a subsequent study to identify whether any participant would provide a report consistent with how they discovered the solution. Participants were provided with the original “brushing” hint or a new hint involving an experimenter twirling a weight tied to the end of one cord while drawing attention to it as a possible help. Thus, it differed from the original hint because its presentation was intentional rather than accidental and the participant was informed that the hint was potentially useful. However, the new hint proved ineffective in eliciting discoveries of the pendulum solution. Maier then undertook a study in which the new hint was provided several minutes before the original hint. The results revealed that both hints were required to discover the solution. However, all participants who discovered the solution reported that the new hint helped them. None mentioned the original hint. Thus, the participants not only failed to report the hint that helped them (i.e., the original hint) but also reported a hint that did not help them (i.e., the new hint). These quite striking findings were among a variety of study findings reviewed by Nisbett and Wilson (1977) that led them to conclude that individuals have specific limits on access to the thoughts mediating their decision and actions.

Telling Only What We Are Thinking; Ericsson and Simon’s (1980) Review

In contrast to the review by Nisbett and Wilson (1977), Ericsson and Simon (1980) proposed that people can provide accurate reports about their cognitions but only under

specific elicitation conditions. Ericsson and Simon adopted the information processing paradigm within which short-term memory (STM) contains a subset of the information being processed during ongoing cognition. They proposed that information attended to (hereafter "heeded") in STM during task performance is the only information about cognition that is accessible and can be verbalized. The process of directly reporting heeded information is termed level 1 or level 2 verbalization (the difference between these levels is not germane here). Specific study conditions offer the constraints necessary to elicit level 1 or 2 verbalization. With departures from these conditions, participants are afforded opportunities to verbalize information not heeded during task performance (e.g., by accessing implicit theories) and thus not a product of any cognitive process mediating performance, resulting in less-valid data. This process is termed level 3 verbalization.

During ongoing activity, information in STM is available for a few seconds only; as new information is heeded, previous information is lost. Unless information heeded in STM is also encoded in long-term memory (LTM), the principal means of obtaining level 1 or 2 verbalization is to ask participants to verbalize their thoughts as they are experienced during task performance. This method is termed *concurrent reporting*. Some information remains in STM briefly after task completion and may be elicited by asking participants immediately following task completion to recall thoughts experienced during the task. This method is termed *immediate retrospective reporting*. In contrast to the concurrent and immediate retrospective reporting methods, Ericsson and Simon's (1980) review revealed that methods used in many studies of thinking involve instructions that do not constrain participants to report about thinking experienced during a task. Instead, these studies afford participants opportunities to report about thinking in more general terms (e.g., What do you think about as you prepare to dive?), allowing them to draw on implicit theories rather than on information related to their performance of the study task, leading to level 3 verbalization.

Level 1 and 2 verbalization is also more likely to occur when participants are provided with undirected probes. With concurrent and retrospective reporting, participants are asked to verbalize thoughts experienced, which means that a thought not experienced is not reported. However, Ericsson and Simon's (1980) review revealed that many studies of thinking involve directed probes that direct participants to report their thinking in relation to a specific subject (e.g., Why did you chose the [high calorie meal] on the menu?). Ericsson and Simon proposed that directed probes for types of information that participants do not have directly accessible for recall may force participants to make inferences about their thinking (which are often informed by implicit theories), leading to level 3 verbalization.

Ericsson and Simon (1980) highlight sources of evidence in support of their claims. One such source is the consistency between known problem solution pathways and verbal reports of solution pathways reported concurrent with attempts to solve those problems. Particularly in well-structured domains, such as mathematics, a task analysis can be performed to identify plausible solution pathways for a given problem. We use a simple example here to demonstrate this (for detailed examples, see Ericsson & Simon, 1993). The sum 18 plus 16 is likely to be solved only a few plausible ways, where two of these are as follows. The 8 from "18" could be added to the 16 to make 24 and then the remaining 1 (which is a 10) from the "18" could be added to 24 to make 34. Alternatively, the 1s, which are 10s, could be added to make 20, and then the 8 and 6 could be added to make 14, which is then added to the 20 to make 34. Now imagine a participant asked to think aloud while performing this sum provides the following report: "Errrr…20..errr. 14.. 34". This report is consistent with the second of our proposed solution pathways. Ericsson and Simon (1993) review a variety of studies providing evidence of consistency between concurrent verbal reports during problem solving and identified solution pathways achieved via task analyses.

A second source of evidence supporting the framework proposed by Ericsson and Simon (1980) is the consistency between verbal reports of thinking and behaviour during task performance. An example of a study reviewed by Ericsson and Simon that provides such evidence was conducted by Schwartz (1966) on concept learning. In the study, which is simplified here, male participants were asked to sort cards displaying symbols into two compartments. They were directed to sort the cards according to a particular rule concerning the card symbols, such as "all cards displaying a hexagon must be placed in the right-hand compartment". Prior to the task, participants were informed about various types of rule that might apply but not told the specific rule that did apply and thus were left to learn the rule as they sorted the cards. After placing each card into one of the two compartments, the participant was asked for his hypothesis about the rule governing card sorting by responding to a statement such as: "Cards with hexagons go in the right-hand compartment". After responding, the participant received feedback about which compartment the previously sorted card actually belonged in, allowing the rule to be learned over time. Being contested in the study was that participants' verbalizations about the rules governing their behaviour are disassociated from their actual behaviour, yet Schwartz showed that participants' sorting behaviour was consistent with their hypothesis about the rule governing sorting on all but 2 of the 1962 study trials. According to Ericsson and Simon's (1993) framework, Schwartz's participants could report the reason for their behaviour accurately because they were probed about this reason in relation to a specific episode of task behaviour and immediately following this behaviour, when relevant information was likely to remain in STM. In contrast, the study participants were not asked what rules govern their behaviour generally, and they were not asked at some point in time distal from any actual episode of task performance.

Returning now to Maier's (1931) study, how can the theoretical framework underpinning the think aloud method explain how Maier's participants' accounts of their problem-solving strategies were often unrelated to the strategies they actually used? We propose two answers to this question. First, Maier's testing phase appears quite lengthy, and thus the time lag between a given problem and being probed about its solution is probably great enough that no relevant information remained in STM. Second, participants were not directed to only recall thoughts from the solution process but were instead encouraged to explain and elaborate on their thinking; for example, "the subject was asked to report where he got the idea of his last solution" (p. 182). These instructions likely provided opportunities for responses based on implicit theories.

In this section, we presented the theoretical framework underpinning the think aloud method and described how this framework is proposed to address shortcomings of more traditional interview-based methods of understanding participants' thinking. Next, we bring the think aloud method to life within the sport, exercise, and health arenas by presenting an example of its use in the study of skilled performance in the sport of golf.

Example of the Use of the Think Aloud Method in Research on Sport, Exercise, and Health: A Study of the Cognitive Mediation of Golf Putting

In the last 20 years, researchers of sport, exercise, and health have begun to use the think aloud method to better understand thinking in relation to the topics they study. We present one such study here (Arsal et al., 2016) with three aims. We wish to showcase the method's use and utility, outline an appropriate application of the method to guide its future use, and present and explore the function of some actual thoughts. We have stylised the presentation of our study accordingly. We expand our description of parts of the study methods concerned with applying the think aloud method and with data resulting from this

application, and we abridge other parts of the study (e.g., statistical analyses). For more detail, see Arsal et al. (2016). Nonetheless, we first describe the study aim and hypotheses because an understanding of these will afford a better appreciation of our use of the think aloud method and its potential beyond our study.

Study Aim and Hypotheses

The aim of our study (Arsal et al., 2016) was to test predictions differentiating the automaticity and cognitive control accounts of skilled athletic performance. Whereas accounts of skilled performance based on automaticity (Beilock & Carr, 2001; Fitts & Posner, 1967) emphasize reduced cognitive involvement in advanced skill, other accounts propose that skilled performance relies on increased cognitive control (Ericsson & Kintsch, 1995). In the cognitive control account of skilled performance, skilled performers are theorised to increase cognitive control over strategic elements of task performance (e.g., adapting to a basketball opponent's changing defence) versus simpler, lower-order elements of task performance (e.g., dribbling in basketball). The predictions of these accounts were tested by using the think aloud method to assess less- and more-skilled golfers' thinking as they putted under conditions that differed in complexity and thus need for strategic control.

According to the automaticity account, skilled performers would be predicted to recognize complex (but not atypical) putting conditions and directly retrieve an appropriate integrated response from LTM. Consequently, we hypothesized that the amount of thoughts verbalized by more-skilled golfers should be few and unaffected by increases in putt complexity. In contrast, the cognitive control account predicts that skilled performers maintain cognitive control over task components, and strategic components particularly, and consequently more thoughts would be generated with increases in task complexity. Therefore, we predicted that, as putt complexity increases, more-skilled golfers should verbalize more thoughts generally, and, in particular, more strategic thoughts than thoughts

related to lower-level movement mechanics. For less-skilled golfers, both accounts of skilled performance predict that more cognitive control is necessary, and thus more thoughts should be verbalized, with increases in putt complexity. Lastly, we predicted that less-skilled golfers would verbalize more thoughts than more-skilled golfers according to the automaticity account (i.e., because less-skilled performers do not perform as automatically) and the reverse pattern would be predicted by the cognitive control account.

Study Methods

Participants, putt task, and putt complexity conditions. To test the study hypotheses, we asked two groups of 26 golfers to make putts on an artificial green: A more-skilled group had an average handicap of 4 and a less-skilled group an average handicap of 23. We manipulated putt complexity by asking golfers to complete a block of 4 putt trials over a "short" distance of 101 cm (3.3 ft) and another such block over a "long" distance of 203 cm (6.7 ft). Within each block of trials, a single putt trial involved taking two putts from the same starting location on the green, but at the beginning of each new trial, a different starting location on the green was assigned. Therefore, the first putt within a trial was always taken from a starting location on the green that was *different* from starting location used on the previous putt (i.e., the second putt in a previous trial); and the second putt within a trial was always taken from a starting location on the green that was the *same* as the starting location used on the previous putt (i.e., the first putt taken in that trial).

We included another manipulation of task complexity by asking the golfers to perform the two blocks of trials described under two stress conditions. In a "low stress" condition, golfers were asked to make their putts as they would in competition. In a "high stress" condition, golfers were informed: they would be filmed and the film of their performance assessed by a golf coach; their performance would be ranked against other participants; and there was a cash prize for the best putt performance. Manipulation checks

revealed each group of golfers perceived the long putt as more difficult than the short putt and the high stress condition as more stressful than the low stress condition.

Elicitation of concurrent think aloud reports. We followed Ericsson and Simon's (1993, p. 375-379) procedures for eliciting concurrent think aloud reports during the trials. Prior to testing, participants received standardized instructions to concurrently think aloud. These included (a) informing the participant that they would be asked to complete various tasks including putting tasks, and (b) asking the participant to talk aloud everything that they say to themselves silently as they perform the tasks, acting as if they are alone in the room speaking to themselves. If participants were silent for any length of time during the tasks, they were reminded to keep talking aloud. Participants then completed two "warm-up" tasks. First, participants thought aloud while solving alphabet-based problems, including: What is the fourth letter before M in the alphabet? Participants received feedback until their verbal reports provided no evidence of explanations and descriptions of their thinking (i.e., of level 3 reports, Ericsson & Simon, 1993). Second, participants practiced thinking aloud while putting twice over 89 cm (2.9 ft). Participants were asked to think aloud from when they retrieved a ball from a stand adjacent to the green to begin the putt all the way through to putt completion.

Procedures. Each participant completed the four blocks (two putt length by two stress condition) of four trials, where a trial involved two putts, for a total of 32 putts. The orders of the putt length and stress condition were fully counterbalanced. Within each trial, participants retrieved one ball from a stand located by the green to complete the first putt and then returned to the stand to retrieve the ball for the second putt. They were asked to think aloud from when they retrieved the ball to begin the first putt all the way through until they had the completed the second putt. Participants' verbal reports were recorded electronically.

Initial data processing. Recorded verbal reports were then transcribed for a given trial from when the ball was collected from the stand adjacent to the green for the first putt to the point of putter-ball contact on the second putt. As a first stage of data processing, a participant's verbal reports for a given trial were broken into separate thought statements, such as "This putt is longer" by identifying the smallest units of meaning within the think aloud reports, and natural pauses or intonations in a participant's speech pattern.

Use of a pilot study to develop a coding scheme. A task analysis was undertaken to identify the types and functions of thoughts verbalized during putting. Prior to the main study (described to this point), a pilot study was conducted involving methods similar to the main study but with samples of 11 less- and 9 more-skilled golfers. The resulting data were used to conduct the task analysis. Specifically, we read transcripts of the thoughts verbalized, asking ourselves what each thought was about (i.e., its type) and why the golfer should have this thought (i.e., its function). We also carefully considered the demands of putting tasks more generally, asking ourselves what needs to done to "solve" a given putting task.

Based on this analysis, we made several observations about the putt tasks and golfers' thoughts in relation to them. First, golfers typically verbalized multiple thoughts during a putt (M = 7.78, SD = 4.23). Second, these series of thoughts seemed to indicate that putting involves specific subcomponents. Third, the thought series we studied indicated that these subcomponents were often undertaken in a particular order, so that the thought series were often characterised by particular pattern of thoughts that reflected this subcomponent order. Fourth, the order of these subcomponents appeared to be functional; that is, undertaking these subcomponents in this order helped "solve" the putt task. We describe the pattern of thoughts we observed, and the subcomponents to which these thoughts correspond, in the following sections. Note that thought quotes provided in these sections are from our main study, not our pilot study.

Evaluations of previous putts. Thoughts occurring early in the thought pattern observed often concerned evaluations of the quality of the previous putt made. Thus, we considered these evaluations the first subcomponent of the putting task. Evaluations sometimes took the form of evaluations of performance outcome.

That was a good putt, that last putt (P51 less-skilled)

Killed that last putt (P29, more-skilled)

Completely missing today (P16, less-skilled)

Evaluations of positive performance outcomes may function as self-reminders of good performance with the aim of maintaining or enhancing confidence and motivation in preparation for subsequent putts. Evaluations of poor performance may be cathartic but also may function as self-reminders that a higher level of performance is required, and thus there is a need to be more motivated and attentive during upcoming putts.

Other evaluations seemed more diagnostic, involving identifying the causes of errors made, presumably with a view to taking action to avoid these errors on subsequent putts.

Hit that one a little to the right (P33, more-skilled)

For some reason I keep pushing it to the right (P42, more-skilled)

Alright, well, I missed my first two to the right (P12, more-skilled)

Evaluations presumably occur early in within the pattern of thoughts observed because: (a) the previous putt had just been completed, and it is natural that the next thought concerns evaluating that putt and/or (b) there is a desire to appraise the previous putt before preparing to take the next putt, because this appraisal may inform the preparation process.

Assessment of putt properties. The next type of thought in the thought pattern observed concerned assessments of the current putt being attempted. We considered these assessments the second subcomponent of the putting task. In some cases, this assessment took the form of an appraisal of the difficulty of the putt.

Easy putt (P29, more-skilled)

A little awkward angle (P47, more-skilled)

This one is gonna be a little difficult (P41, more-skilled)

This form of assessment may be involved in identifying the difficulty or complexity of the putt, and where more complex putts are detected, alerting golfers to the need to be more motivated and attentive when preparing to execute that putt.

In other cases, the physical properties of the green were assessed, which included: putt distance, the relief of the green, known in golf as "break"; the green's surface friction, known in golf as "speed" or "stimp", which affects ball roll; and the qualities of the hole.

Just a short little three-footer, two-footer (P18, more-skilled)

Ok, don't see any breaks (P22, more-skilled)

The speed of the green (P18, more-skilled)

It's a little different from an actual deep hole (P17, less-skilled)

In addition, assessments were made of the physical properties of the equipment used such as the softness/hardness of the ball and the nature of the putter provided by the researchers.

Maybe a little softer than other balls (P5, less-skilled)

The putter, how heavy it is (P45, more-skilled)

Regarding the overall function of the thoughts in this category, we theorised that golfers know how to make a putt generally but each individual putt has a different complexity level, which is determined in part by its unique physical properties. Therefore, golfers must adapt their general putting skill to these unique aspects of the putt. A prerequisite to effectively adapting the skill is effectively detecting these unique aspects, and it is this detection process that is the function of the thoughts in this category.

Response identification. The next thought type in the pattern concerned identifying and planning how to make the putt response. We considered this process as the third

subcomponent of the putting task. Most thoughts in this category pertained to identifying and planning the angle or path of the ball to the hole and the strength of the putt stroke required to make the ball travel this path.

So don't want to miss to the right again, aim left (P12, more-skilled)

Just aim inside that corner of the little cup (P43, more-skilled)

Hmmm…make sure not to hit this too hard (P47, more-skilled)

These thoughts appeared to function to mediate the putt adaptation process on the basis of assessments, made earlier, of the unique aspects of the putt. Hence, response identification thoughts tended to occur after assessment thoughts in the thought pattern we observed.

Mechanics. The thought type observed next in the pattern concerned the physical positioning and movement of the body and putting equipment. One form of these thoughts was related to the positioning of specific body parts, including the feet, back, head, shoulders, wrists, and hands, and in particular the grip of the hands on the putter. These thoughts often contained references to the orientation of these body parts to other body parts, the putter, and the hole.

Feet (P10, less-skilled)

Elbow point towards the hole (P51, less-skilled)

Butt out (P46, more-skilled)

Align your hands and feet (P24, more-skilled)

Other thoughts in this category were concerned with preparing to move the putter, which sometimes included practice strokes, and with actually moving the putter to make the putt.

Square up my putter to the hole (P8, less-skilled)

Aim the putter head to that line (P9, more-skilled)

Pendulum, grandma, pendulum, just like grandma said (P10, less-skilled)

Make sure I take it back slow and follow through fully (P24, more-skilled)

The function of the thoughts in this category appeared to be to prepare the golfer physically and motorically to deliver the desired movement response and then to mediate the golfer's actual delivery of that response. We used the label *mechanics* to capture these concepts, and considered mechanics as the fourth subcomponent of the putting task. Identifying a desired movement response is obviously a prerequisite to preparing to delivering that response, and thus thoughts concerning mechanics tended to follow those concerning response identification in the observed pattern of thoughts.

Psychological preparation. The final type of thought in the observed pattern was concerned with a desire to achieve a particular psychological state. These thoughts often evidenced self-directed affirmations "I'm aimed good, I feel comfortable…" (P 21, more-skilled) or instructions "Stay focussed" (P6, less-skilled). Typically, these thoughts concerned competence, confidence, and/or calmness, as in the quote above by P21, or attention, as in the quote above by P6. We considered that the function of these thoughts was one of psychological preparation to putt; that is, they were involved in helping the golfer achieve a psychological state they perceived as conducive to the effective performance of the putt. We considered psychological preparation as the fifth and final subcomponent of the putting task.

This pattern of subcomponents, which runs evaluation of previous putt, assessment of putt properties, response identification, mechanics, and psychological preparation, is to some extent evident from an examination of only the four examples of thought series presented in Figures 1 and 2; consider that we identified this pattern from many more examples of thought series.

Insert Figures 1 and 2 about here

Other thoughts: Goal statement, ambiguous, and task-irrelevant thoughts. We also identified three other thought types that did not seem to form part of the pattern of thoughts identified but instead appeared at various locations within the thought series

verbalized during the putts. The first was concerned with momentary goals and attention orientation during the putt task, where examples included “Alright, so now” (P28, less-skilled) and “Let’s see here” (P2, less-skilled). The second involved ambiguous thoughts, such as “That’s kind of hmm” (P3, less-skilled) and “I’m not really sure, maybe it's just” (P10, less-skilled), where we were not able to derive any meaning from the verbalised thought. The third involved thoughts not directly relevant to the task; examples included “Fixing my clothes real quick” (P7, less-skilled) and “I should have eaten before I came” (P25, less-skilled). We did not consider these thought types to reflect particular subcomponents of the putting task.

Creating Codes to Test the Study Hypotheses

Our hypotheses were concerned with differences between golfer skill levels in the amount of overall thoughts verbalized during a putt and in particular with strategic elements of task performance. These strategic elements included the need to adapt to changes in task complexity, and were in contrast to lower-level aspects of task performance such as actual movement control. Thus, our next step was to consider how thought types identified from our raw data related to these two theory-level thought types (i.e., to strategy- and movement-related thoughts). We considered that the function of the thoughts types in our pilot study labelled (a) assessment of putt properties and (b) response identification was to help the golfer adapt to the unique aspects of a given putt, and therefore, these thought types were high-level, strategy-related thoughts. By comparison, we considered that the mechanics thoughts identified in our pilot study were lower-level movement-related thoughts.

Consequently, we created a multi-level coding scheme. The first and lowest level featured eight categories: *evaluation of previous putt,* Assessment of putt properties (hereon *assessment), response identification, mechanics, psychological preparation, goal statement ambiguous, and task-irrelevant*. The next level featured two categories: *mechanics thoughts,*

containing mechanics thoughts from the first level, and *strategy thoughts*, containing assessment thoughts and response identification thoughts from the first level. The final and highest level, *task-relevant thoughts*, contained all thoughts from the first level except task-irrelevant thoughts. We then coded all of the data from the *main* study using the first-level codes and a mutually exclusive and exhaustive procedure, and subsequently categorised first-level coded thoughts under the higher-level codes. Inter- and intra-rater coding reliability procedures were employed and the results indicated that reliability was high.

Our first level of code allowed us to explore quantitatively the validity of the pattern thought types observed during putts, which was: evaluation of previous putt, assessment, response identification, mechanics, and psychological preparation. For each putt in the main study, we identified the first occurrence within that putt of each of these five coded thought types and expressed this value as a decimal fraction of the total amount thoughts within a putt, so that an "assessment" thought verbalised first in a putt with four total thoughts was scored .25. The median (due to some non-normality of distributions) first occurrence value across the 1664 putts in the study was .25 for evaluation of previous putt, .40 for assessment, .50 for response identification, .50 for mechanics, and .66 for psychological preparation. These results are quite consistent with our identified pattern, lending some validity to our analysis of the subcomponents of the putt task, and the pattern of thoughts reflecting these subcomponents.

Study Results

In this section, we first present results concerned with hypotheses about differences in thoughts verbalized between less- and more-skilled golfers. Next, we present results concerned with hypotheses about the effects of putt complexity on thoughts verbalized by the golfers.

Differences in thoughts verbalized between less- and more-skilled-golfers. Our first finding was that both groups of golfers provided clear evidence of thinking as they prepared to putt. Of the 1664 putts made in the study, where each golfer made 32 putts, no thoughts were verbalized during only 10 (<1%) of these putts.

Recall that an automaticity account of skilled golf performance would predict that the amount of thoughts verbalized by the more-skilled golfers should be uniformly few, and less than that for less-skilled performers. The reverse pattern would be predicted by the cognitive control account, where in particular more-skilled golfers would be expected to verbalize more strategic (vs. mechanics) thoughts than their less-skilled counterparts.

We found that, on average, more-skilled golfers took approximately 22 seconds (M = 22.18 s) to make a putt, during which time they verbalized an average of approximately six task-relevant thoughts (M = 5.97, SD = 2.52). Statistical tests showed this amount of thoughts was significantly more than the less-skilled golfers who verbalized an average of approximately four such thoughts (M = 4.08, SD = 2.22) over their 18 second (M = 18.11 s) average putt time. These findings can be appreciated in Figures 1 and 2, which each contain an example of a thought series for a golfer from each of the two groups. It is clear from the figures that the more skilled-golfers in the figures verbalize more thoughts during the putts and take longer to make the putts.

In addition, the group difference in the amount of task-relevant thoughts was accounted for more by strategy thoughts than mechanics thoughts. Statistical tests showed that more-skilled golfers verbalized significantly more strategy thoughts (M = 1.47, 95% CI [1.11, 1.88]) than their counterparts (M = .67, 95% CI [0.44, 0.96]), but the groups did not differ significantly for mechanics thoughts. In sum, compared to less-skilled golfers, more skilled golfers think more, and in particular more about strategic elements of the putting task.

These results are more consistent with the cognitive control account than with the automaticity account of skilled performance.

The standard deviation values for the amount of putts verbalized by the two groups show that the majority of golfers verbalized between two and eight task-relevant thoughts per putt. Provided below are examples of thought series ranging in length from two to eight thoughts.

Make sure it's straight; and putt (Two thoughts, P1, less-skilled).

There is a little break in this putt; there is like, in the middle; straight back, straight through. (Three thoughts, P3, less-skilled).

Alright, well, I missed my first two to the right; so don't want to miss to the right again, so aim left; probably hit it too far to the left; but best idea is to keep it slow. (Four thoughts, P13, more-skilled).

Back to this trusty old ball that keeps going in; what a long putt; it's like 8 feet; no, it's like 7 feet; gotta make these ones for not making these earlier, come on. (Five thoughts, P16, less-skilled).

Ok, I don't see any breaks; obviously straight; just have to roll it right; twice as long; twice the stroke; nice rhythm. (Six thoughts, P24, more-skilled).

Alright, this time I gotta hit a little bit harder; but not too much harder; same thing; align my feet; look at the hole, look at the ball; line the putter up; just straight to the target. (Seven thoughts, P9, less-skilled).

So this one is dead straight; so I'm gonna aim at the middle of the hole; aim the logo; make sure it's straight; try to do some practice strokes; along that same line parallel to the logo; make sure it's aimed right; and then go. (Eight thoughts, P10, more-skilled).

Effects of putt complexity on thoughts verbalized by less- and more-skilled golfers. Recall that the automaticity account predicts that the amount of thoughts verbalized by more-skilled golfers should be few, and unaffected by putt complexity. In contrast, the cognitive control account predicts that more-skilled golfers would verbalize more thoughts, and strategic thoughts in particular, following increases in putt complexity. Both accounts predict that less-skilled golfers would verbalize more thoughts as putt complexity increases. We manipulated putt complexity by increasing putt length and level of stress.

Statistical tests showed that increasing putt length from 3.3 to 6.6 ft led to a significant increase in verbalized task-relevant thoughts for both groups, but the increase was significantly larger for the more-skilled golfers. Less-skilled golfers verbalized a mean of 3.93 (*SD* = 2.16) thoughts during the short putts and 4.24 (*SD* = 2.31) thoughts during the long putts; whereas the more skilled golfers verbalized a mean of 5.58 (*SD* = 2.66) thoughts during the short puts and 6.37 (*SD* = 2.45) thoughts during the long putts. This finding can be appreciated from the examples of thought sequences provided in Figure 1. It is clear from the figure that both golfers verbalize more thoughts during the long putts and take longer to make those, compared to short putts. It is also clear that the increase in thoughts that accompanies the longer putt length is more pronounced for the more-skilled golfer.

For both groups, the increase in task-relevant thoughts from the short to long putt was accounted for more by strategy thoughts than mechanics thoughts. Golfers verbalized a mean of .92 (95% CI [0.70, 1.17]) strategy thoughts during short putts but 1.15 (95% CI [0.92, 1.41]) strategy thoughts during the long putts.

In sum, the increase in putt length led to an increase in the amount of thoughts verbalized by the more-skilled golfers, and, furthermore, this increase in thoughts was greater than that also observed for the less-skilled golfers. The increase in thoughts for both groups was accounted for more by an increase in strategy thoughts than mechanics thoughts. These findings are supportive of the cognitive control account of skilled performance, and inconsistent with the automaticity account.

Turning now to effects of stress, statistical tests showed that increasing stress led to a significant increase in task-relevant thoughts for both groups on the first, but not on the second, of the two putts in a trial. On the first putt, golfers verbalized 5.01 (*SD* = 2.70) thoughts in the low-stress condition but 5.51 (*SD* = 2.61) thoughts in the high-stress condition. This finding is demonstrated by the examples of thought sequences in Figure 2. It is clear from the figure that both golfers verbalize more thoughts during the high stress condition but only for the first putt in the trial. There were no significant differences in mechanics or strategy thoughts between the low- and high-stress conditions for the first putt, which means that the increase in task-relevant thoughts across these stress conditions on this putt was not differentially accounted for by mechanics thoughts or strategy thoughts.

In sum, the increase in stress led to an increase in the amount of thoughts verbalized by the more-skilled golfers, as well as the less-skilled golfers, but only for the first of the two putts in a trail. We interpret this finding as reflecting the novelty of the first putt, compared to the second putt, in the two-putt trial; the novel first putt required more adaptation than the second putt, and thus was effectively more complex, requiring more thought. Once again, these findings are supportive of the cognitive control account of skilled performance, and inconsistent with the automaticity account.

Overall summary of results. To conclude, the more-skilled golfers in our study verbalized more thoughts during putting than the less skilled golfers. The more-skilled golfers also increased their thinking, particular about strategic elements of the task, when putt conditions became more complex. These two overall findings are supportive of the cognitive control account of skilled performance, and are inconsistent with the automaticity account.

Considerations and Guidelines for Applying the Think Aloud Method

In the final sections of our paper, we aim to help researchers interested in applying the think aloud method. We consider first how the think aloud method might compliment traditional interview and other qualitative methods and then outline common pitfalls in applying the think aloud method. Next, we discuss a common concern about the use of the think aloud method, and finally we conclude with a look to the future.

How Might the Think Aloud Method Compliment Traditional Interview and Other Qualitative Methods?

We show here how the think aloud method might compliment traditional interview methods. To this end, we provide one worked example concerning exercise and health, and another concerning sport.

A central aim in researchers' efforts to enhance the health and wellbeing of our societies is to understand people's motivation to engage in exercise and physical activity (Lindwall et al., 2017). Biedenweg et al. (2014) used semi-structured interview methods to study 39 older adults' suggestions for marketing strategies that would optimise older adults' participation in physical activity programmes. An interview guide was developed containing questions designed to elicit these suggestions. No details of the interview questions or examples of quotes elicited by these questions were outlined in the study. Nonetheless, it is

likely that the questions involved probes that: (a) were directed rather than undirected; and (b) did not constrain the participant to report about thinking experienced during a specific episode in which they appraised marketing materials but afforded opportunities for reports concerning thinking about marketing materials in more general terms. An example of such a probe might be: “What advice would you have about how to market the programme to older adults?” (Recall that, by comparison, Ericsson & Simon’s (1993) framework recommends using *undirected* probes to elicit recall from *specific episodes* of task performance.) Thus, the questions posed to the participant in the study by Biedenweg et al. were likely consistent with those used in traditional individual semi- or unstructured interview approaches (Smith & Sparkes, 2016).

Ericsson and Simon’s (1993) framework could be applied to the design of this study so that think aloud methods could be used jointly with the traditional interview methods to better understand participants’ reactions to, and appraisals of marketing materials for exercise programmes. Participants could provide concurrent verbal reports while appraising marketing materials. Analysis of thoughts and patterns of thoughts involved in this appraisal process might illuminate important reasons and motives affecting the choice to participate in the programme. The participant then could be interviewed following the appraisal process as per Bidenweg et al.’s (2014) original design. It would be useful within the subsequent analytical process to identify points of convergence and divergence between reports elicited by these different methods. We believe the results of this form of analysis would offer novel and rich insights that would significantly advance our understanding of this research topic.

Physical and psychological preparation for elite sports performance under pressure has long been a topic of interest to sports scientists (Eccles et al., 2011). In a fascinating study, Jackson and Baker (2001; see also Eccles, 2012) studied the prekick routine of one of the most successful rugby union goal kickers of all time. The routine was first examined at a

behavioural level by asking the participant to attempt various kicks on an empty rugby field and observing how kick difficulty affected the number of preparatory behaviours included within the routine, such as number of footsteps taken. The participant was then interviewed at the rugby ground about mental preparation strategies he used within the routine. No details of interview questions were outlined in the study but all 13 interview quotes provided suggested that the questions involved probes that (a) were directed rather than undirected and (b) did not constrain the participant to report about thinking experienced during a specific kick episode but afforded opportunities for reports about psychological strategy use in more general terms. An example is as follows: "I imagine putting all my problems into a black box, and closing the black box…" (p. 59). (Again, recall that Ericsson and Simon's (1993) framework recommends using *undirected* probes to elicit recall from *specific episodes* of task performance.) Thus, as in the study by Biedenweg et al. (2014), the questions posed to the participant were likely consistent with those used in traditional individual semi- or unstructured interview approaches.

Ericsson and Simon's (1993) framework could be applied to the design of this study so that think aloud methods could be used jointly with traditional interview methods to better understand the mental strategies used in the prekick routine. The participant could provide concurrent verbal reports during a subset of the kick trials and/or retrospective verbal reports following each of another subset of the trials. Ericsson (2006) proposed that participants are unlikely to recall all thoughts experienced during a task when the duration of the task last longer than 10 s and certainly when it lasts longer than 30 s. Thus, the duration of the prekick routine often meets this requirement. The participant then could be interviewed following the kick trials as per Jackson and Baker's original design. Again, the combined use of these different methods would provide researchers working in this area novel and rich insights into this research topic.

A final consideration about the use of the think aloud method by qualitative researchers is that technological advances have given rise to light, wearable, and high-quality video and audio recording devices. In turn, more than ever before, various forms of data can be collected "online"; that is, concurrent with the participant experiencing and dealing with real situations, task, and events. For example, in a case study of cognitive strategies used by an elite athlete by Macquet, Eccles, and Barraux (2012), the athlete agreed to wear video-recording equipment while competing in World Championship events because the modern equipment used was unobtrusive to performance. Consequently, there is a wealth of opportunity to use the concurrent reporting method to study dynamic interactions between an individual's thoughts and their changing environment, in its full contextual richness. Using the think aloud method this way offers a unique complimentary method to the mobile interview techniques employed by qualitative researchers (Smith & Sparkes, 2016).

Common Pitfalls with Applying the Think Aloud Method

Our reviewing of the application of the think aloud method in sport, health, and exercise arenas has revealed that researchers have sometimes misinterpreted guidance on applying the think aloud method (Arsal et al., 2016). We identify some of these common pitfalls below to help researchers apply the method in future studies.

Allowing and encouraging descriptions and explanations of thoughts. In the think aloud method, participants should be asked only to think aloud concurrently or retrospectively. Participants should not be asked to describe or explain, verbally or via other means, their thinking, decisions made, or the basis for how they behave because these procedures provide conditions ripe for reports not based on information in STM. Researchers should be alert to participants instructed to think aloud (e.g., "the first thought I had was…",

using the retrospective method) who begin to stray away from doing this towards reporting about thinking in more general terms (e.g., "that's how I do these problems").

No warm-up exercises. Thinking out aloud everything one thinks about is not particularly natural, especially in the presence of others. Therefore, participants should not be instructed to think aloud without warm-up exercises that train them to do this. We refer the reader to Eccles (2012) and Ericsson and Simon (1993, p. 375-379) for warm up procedures.

Thinking aloud for too long. Little guidance is available about the length of time a participant can be expected to think aloud before motivation wanes and, even with prompts to keep talking, few verbalizations are made. Nonetheless, our experience is that participants should think aloud for a maximum of only a few minutes to maintain quality of reporting.

Concerns about Reactivity

A concern often raised about using the concurrent reporting method is that thinking aloud might affect performance of the primary task (e.g., putting in the present study) and in turn the validity of thoughts elicited in relation to this task. Reviews of studies involving concurrent reporting (Ericsson & Simon, 1993; Fox, Ericsson, & Best, 2011) have revealed that the method typically increases the time required to complete the primary task but does not affect the accuracy of task performance or the nature of the thought processes involved in the task. The task slowing effect might make concurrent reporting inappropriate for some situations, such as during sports competitions, but it does not restrict the method's use in many other situations such as task simulations of the kind employed by Jackson and Baker (2001), described above. Also, checks for reactivity can be made by comparing various behavioural measures of task performance between trials that include a concurrent report and those that do not. We undertook this comparison in our study of putting (see Arsal et al.,

2016) and our findings were consistent with previous reviews: The method increased putt time but did not affect putt performance.

Conclusions

When we want to know what thoughts athletes have about their bodies, sports fans have about their sports, and mentally tough exercisers have in exercise settings, it might be tempting to rely solely on participants' reports of their cognitive processes. However, the review of the literature presented here highlights how these reports may be of limited validity, except under specific conditions. The objective of this paper was to present a method that elicits verbal reports of thinking under these conditions: The think aloud method proposed by Ericsson and Simon (1993). We believe that the qualitative researcher may have given little consideration to this method as an option for understanding thought. We hope this paper can help change this situation so that we can add to the suite of methods available to qualitative researchers of all ontological and epistemological positions; see our proposals in the introduction about how researchers adopting relativist and constructionist positions can make effective use of the method. Aware of the challenges of applying new methods effectively, we have also provided some general guidance about applying the method, a worked example of a study that has done this, and ideas for how the method might be integrated with more traditional qualitative research methods. Finally, we have enjoyed taking this opportunity to present examples of thoughts elicited via the think aloud method and to explore their nature and function in some detail. We look forward in the future to seeing innovative and exciting research that combines more traditional qualitative approaches with the think aloud method.

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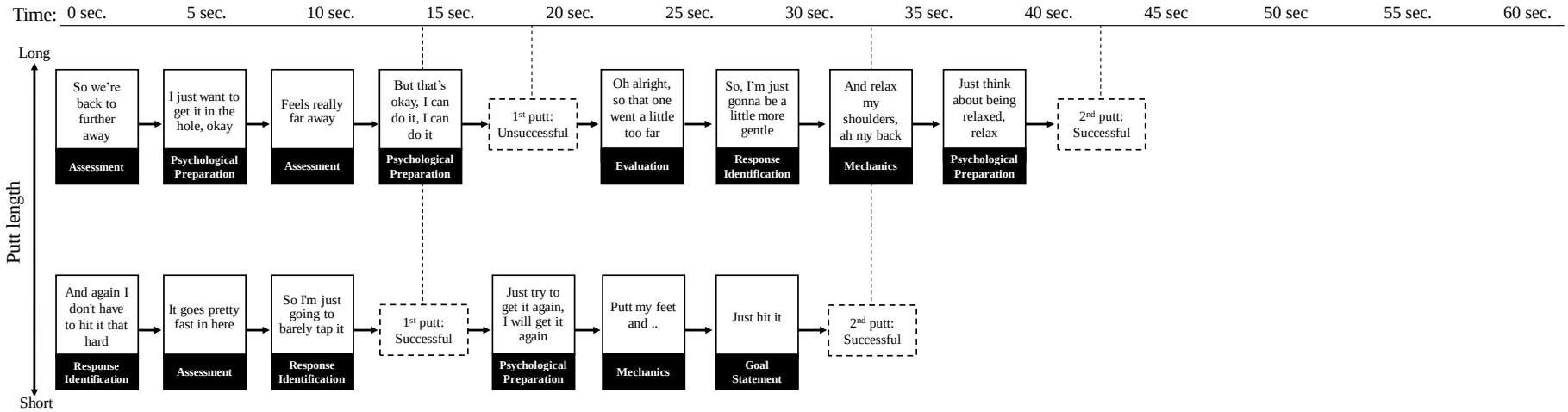
Figure captions

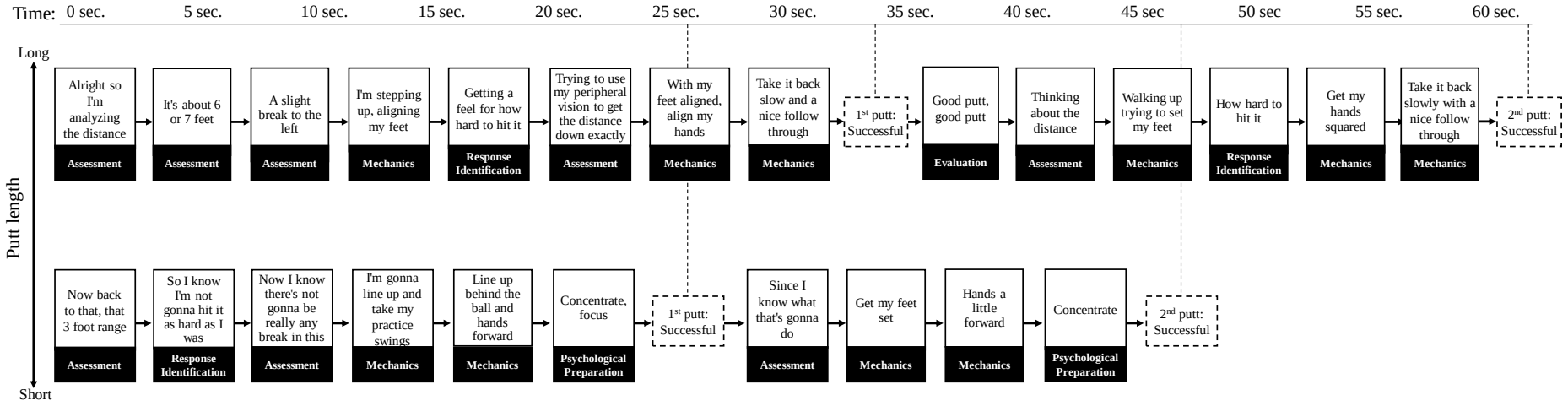
Figure 1: An example of a verbalized thought series during a trial in the low-stress condition for a less- and a more-skilled golfer. The examples exemplify two key study findings. First, more-skilled golfers verbalized a greater amount of task-relevant thoughts on average during a putt than less-skilled golfers. Second, an increase in putt length led to an increase, on average, in the amount of task-relevant thoughts verbalized by both the less- and more-skilled golfers, but this increase was more pronounced for the more-skilled golfers.

Figure 2: An example of a verbalized thought series during a trial in the long putt condition for a less- and a more-skilled golfer. The examples exemplify two key study findings: First, more-skilled golfers verbalized a greater amount of task-relevant thoughts on average during a putt than less-skilled golfers. Second, an increase in stress led to an increase, on average, in the amount of task-relevant thoughts verbalized by both the less- and more-skilled golfers on the first but not the second of the two putts in a trial.

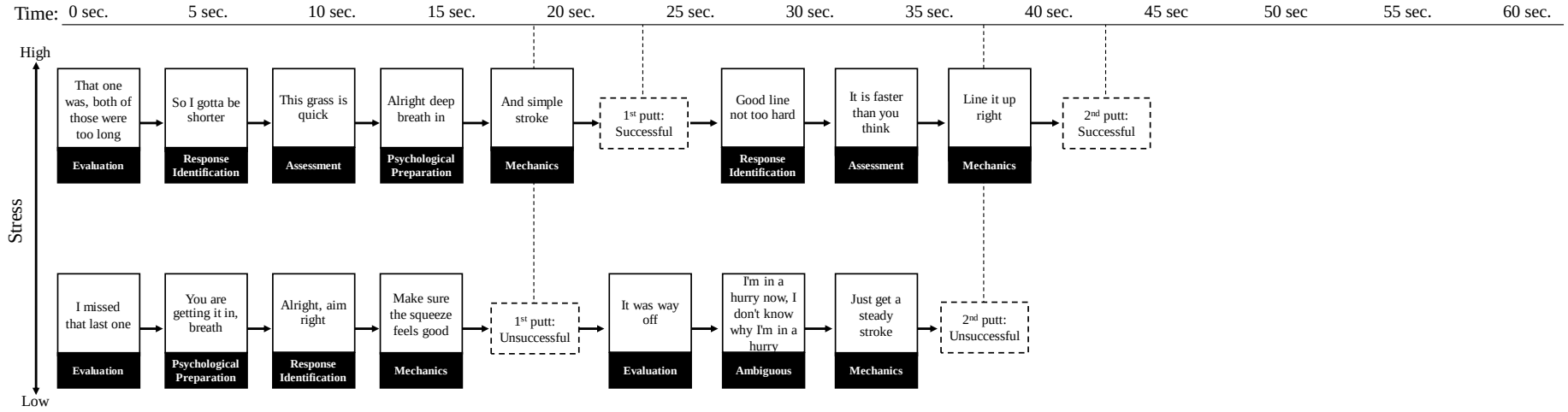
Less-skilled golfers



More-skilled golfers



Less-skilled golfers



More-skilled golfers