The ecological rationality of children's option generation and decision making

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Abstract

In everyday life, before deciding what to do, one has to think about what *could* be done. We investigate option generation from a developmental perspective, testing the predictions of the Take-The-First-heuristic (TTF). Moreover, we examine the influence of time limitation on decision-making processes. Using soccer as a testbed, 6- to 13-year-old children (N = 97) were tested in a video-based option-generation paradigm. Children's performance was aligned with predictions of TTF: Children generated a mean of 2.21 options, did so in a meaningful way and selected the first as final option in 74%. With shorter time, children generated fewer and higher quality options, selected better options and more often the first option as final decision. Further, with age, an increase of the number of options generated and an increase in quality of the final decisions emerged. This age effect was more pronounced with shorter time. Implications for real-life decision-making are discussed.

Keywords: option generation; decision making; heuristics; ecological rationality; development.

Introduction

Imagine being a young, talented soccer player. You are running, alone, through the middle field towards the goal, dribbling one opponent after the other. You are now 20 meters from the goal, facing the opposing defense rapidly closing on you. What should you do? Maybe you should try to dribble the defense, get closer to the goal and shoot from a shorter distance? Should you try to shoot at goal from where you are now? Or should you pass to one of your team members – maybe Jack, approaching from the right? Or Mike, right behind you?

Most of the time, in everyday life, before deciding what to do, one has to think about what *could* be done. In this paper, we investigate option generation from a developmental perspective using sport as a testbed. Moreover, we examine the influence of time limitation on option-generation and decision-making processes.

Option generation

A decision-making strategy usually consists of a search, a stopping, and a decision rule, all together defining how and how much information has to be collected before being able to make a decision (Gigerenzer & Todd, 1999). However, most real-world situations require us to generate alternative options *before* making a decision, rather than selecting one from a set of options pre-defined and generated by an experimenter (Payne, Bettmann, & Johnson, 1988).

Very little is known about how people generate options (for an exception see e.g., Johnson & Raab, 2003), as most research on decision-making focuses on the other three building blocks of decision making. The Take-The-First heuristic (TTF) is a cognitive model that captures option generation and decision making in familiar, yet ill-defined tasks (Johnson & Raab, 2003; Raab, 2012; Raab & Johnson, 2007). In the TTF the building blocks are formally defined as follows: A *search rule,* suggesting that alternative options are generated in order of validity meaning that subjectively better options are generated earlier; A *stopping rule*, according to which the generation phase should stop after two to three options have been generated; A *decision rule*, assuming that people should choose one of the initial options generated (Johnson & Raab, 2003). In this sense, people would generate a few options and select one of those, rather than exhaustively generating and processing all possible options. However, because those options were generated in order of validity, the decision, although fast and frugal, would tend to be accurate.

Studies with adults and adolescents testing the predictions of the TTF model have previously been conducted in sports (Belling, Suss, & Ward, 2015; Raab, 2012; Ward, Ericsson, Williams, & Williams, 2013). Indeed, because of its naturally occurring dynamics (e.g., decisions to be made under time pressure; many potential alternative actions to be considered), sport is the ideal domain to test whether people use fast-and-frugal decision-making heuristics, such as TTF. These studies show that the performance of experienced handball, basketball, and soccer players is pretty accurately predicted by the TTF model: Players tended to generate alternative options (e.g., shoot at the goal or pass to their teammate) in order of validity and selected as their final decision the first option they had generated.

As for adults, most decision-making research with children focused on information search (see Davidson, 1991, 1996; Gregan-Paxton & Roedder John, 1995, 1997; Howse, Best, & Stone, 2003; Ruggeri & Katsikopoulos, 2013; Ruggeri, Olsson, & Katsikopoulos, 2015) or investigated cue-based decision strategies (Horn, Ruggeri, & Pachur, 2016; Mata, von Helversen, & Rieskamp, 2011). However, to our knowledge, option generation in children has never been studied before.

Time-limitation effects on option generation and decision making

According to the ecological rationality framework (Todd, Gigerenzer, & ABC Research Group, 2012), no strategy is *always* optimal, because the efficiency of a strategy depends on the environmental structure. In this sense, people should be *adaptive* and modify their strategies depending on how effective they are in a given environment (de Oliveira, Lobinger, & Raab, 2014). In many real-life situations, as in sports, decisions have to be taken under limited time, and we know that adults adapt to time limitation by using faster and simpler strategies (Ben Zur & Breznitz, 1981; Payne et al., 1988). In particular, previous studies examining the effects of time limitation on decision-making processes have found that, under pressure, adults tend to increase their information processing speed (e.g., Ben Zur & Breznitz, 1981; Payne et al., 1988) and use more non-compensatory strategies (e.g., Payne et al., 1988). On the same line, in a study with adult soccer players, Belling and colleagues (2015) found that time limitation reduced the number of task-relevant options generated, although it did not impact the quality of players' decisions.

What about the effects of time limitation on children's decision-making? We know that children are *ecological learners*, able to adapt their learning strategies to the characteristics (e.g., the statistical structure) of the task at hand (Horn et al., 2016; Nelson, Divjak, Gudmundsdottir, Martignon, & Meder, 2014; Ruggeri & Lombrozo, 2015), and they do so already by age four (Ruggeri, Sim, & Xu, 2017). However, Davidson (1996) investigated the influence of time limitation on children's (7- to 10-year-olds) information search behavior and found that time pressure promoted faster, but generally not more selective searching. In this sense, it is unclear whether children would adapt their option generation and subsequent decision-making strategies depending on the time available.

The present study

In the present study we use soccer as a testbed for a dynamic, real-life decision-making situation children have experience with. In particular, we extend previous research in two ways. First, we investigate for the first time children's (6- to 13-year-olds) *option generation* process, testing the predictions of the TTF model. In general, children have been shown to use simple, non-compensatory information-search strategies (Davidson, 1991; Ruggeri & Katsikopoulos, 2013), and specifically adolescent handball players have been shown to act according to TTF (Johnson & Raab, 2003), we expect children to make use of the TTF heuristic. Moreover, in line with studies that investigated decision-making from a developmental perspective and showed an increase of selective, non-compensatory strategy use with age (Davidson, 1991, 1996), we further expect older children to rely more on the TTF heuristic than younger children.

Second, we explore whether and how *time limitation* influences the option generation and decision making of children. In particular, based on prior research, it is unclear whether children would adapt their option generation and decision-making strategies under time limitation.

Method

Participants

Ninety-seven children, all male, participated in this study (M_{age} = 10.49 years, *SD* = 1.98 years; ranging from 6.67 to 13.50 years). All participants were recruited from a professional soccer academy in Germany. Prior to beginning the study, written informed parental consent, and local ethical review board approval of the study protocol, were obtained.

Materials

We used 21 video scenes of live soccer match footage (three for the practice trials, 18 for the test trials). After a short display of buildup play, the scenes suddenly stopped right before the player in possession of the ball had to make a decision. The duration of the video scenes ranged between seven and eleven seconds, and video duration was unrelated to the study variables (all $p > .05$). We adopted the same task and materials as in Belling et al. (2015) with one difference: Instead of using an occlusion image that displayed field lines and the location of the ball on a blank white screen, we used real play footage that ended in a frozen frame such that all players are visible and the player with the ball needs to decide (see Figure 1). We chose to end the video with a frozen frame to provide participants with a constant, non-memory based game situation allowing the same condition during the entire option-generation test. Materials were presented to children on a touchpad (size: 8.9'').

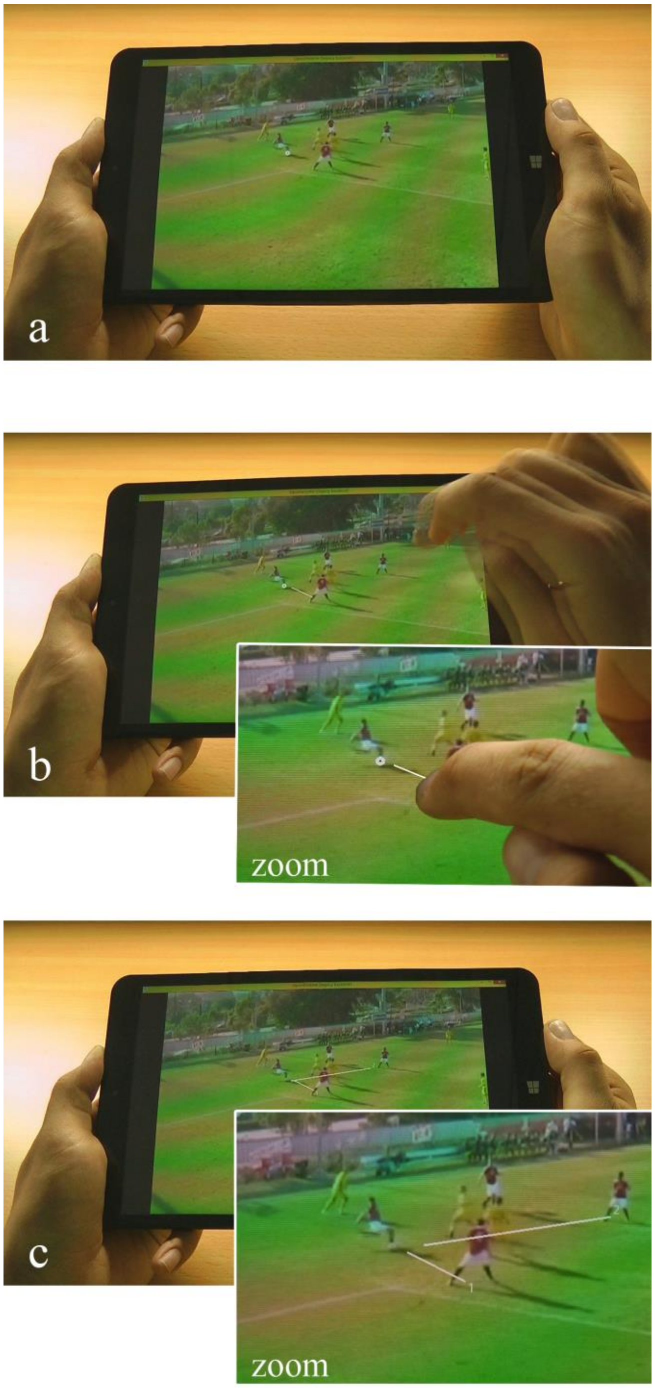

Figure 1: Decision-making test procedure. a) The video stopped right before the player in possession of the ball had to make a decision and ended with a frozen frame. b) The option generation phase in which children generated options. c) Option selection phase in which children saw their generated options and subsequently selected the option they thought was the best.

Design and Procedure

The task was administered collectively in groups of five to nine same-aged children. Within one age group, children were randomly assigned to the testing sessions. Children were asked to sit at individual desks where a tablet was positioned. They were then introduced to the task procedure via a standardized instructional video (duration: 2:51 min) showing a person conducting the decision-making test for one exemplary soccer scene. The instructional video showed exactly which steps children were required to do on their tablets throughout the testing procedure.

The test proceeded as follows: After viewing each of the 21 videos (see above), videos stopped and held on with a frozen-frame, which gave the children time to generate a maximum of six options directly marking them onto the field via touch-pad (see Figure 1 a, b). The first three videos were practice trials, used to familiarize participants with the test. During this familiarization phase children could ask clarifying questions to the experimenter. The other 18 video scenes were used as test trials and were randomly assigned to either the short-time (9 videos) or the long-time (9 videos) condition. In the long-time trials, children were given 30sec to generate options, whereas in the short-time trials participants were given 7.5sec to generate. The order of presentation of the test videos was randomized, irrespectively of to which condition they were assigned. Afterwards, participants were asked to select among the options they had generated the one they thought was the best (see Figure 1 c).

Results

Results were analyzed with respect to developmental differences on four outcomes: (1) the mean number of options generated across all 18 tests; (2) quality of the generated options; (3) quality of the selected options; (4) participants' *dynamic inconsistency,* which is the rate at which children selected as the best option the one they had generated at first. Dynamic inconsistency rates were computed as the relative frequency that the first option was not selected by players to be their final decision: Number of videos minus the frequency of the first generated option being the final decision divided by the total number of videos. Finally, we tested the effect of the time limitation manipulation on above-mentioned outcome variables.

To assess the quality of (2) the options generated and (3) option selected, two experienced youth soccer coaches independently generated options for the 18 test videos presented and rated the quality of each option they had generated on a 10-point scale (from 0, 'not at all good', to 10 'very good'). Overall, coaches generated a total of 104 options for the 18 test videos. That is, a total of 52 options were generated by each coach (M = 2.89 options per coach per video). Of the 52 options generated independently, 42 identical options were generated by both coaches indicating an 81% overlap between coaches. The quality of the options generated only by one coach or not generated by the coaches at all was scored with 0 'not at all good'. Based on the moderate inter-rater agreement for the quality of all options generated (ICC = .52, p = .01), quality scores for each option were calculated by averaging coaches' quality ratings.

Option Generation, Decision Making, and Developmental Effects

Children generated a mean of 2.21 options (*SD* = 0.65). Overall, the mean quality of the first option children generated was 4.72 (*SD* = 0.99). We conducted a repeated measures MANOVA with the within-subject factor serial position of option (1-6) and quality as a dependent variable. This analysis revealed that children generated options in a meaningful way indicated by a significant decline of option quality across the serial position, Greenhouse-Geisser corrected $F(2.70, 259.43) = 859.56$, $p < .001$, $\eta_p^2 = .90$.

The mean quality of the option selected as the best was 4.45 (*SD* = 1.06). Most importantly, children selected the first generated option as the best one in 74% of the cases (SD = 18.59). Compared to options generated at later serial positions, the first option generated was selected to be the final decision more frequently, χ^2 (5) = 4411.70, $p < .001$. This was reflected in a dynamic inconsistency rate (i.e., the mismatch between the first option generated and final decision) of 0.26 (*SD* = .19). This is a relatively low value, considering that a random selection would have resulted in a dynamic inconsistency rate of 0.55, resulting from: 1 – (1 / 2.21). The more options children generated, the higher was the dynamic inconsistency of their decisions, $r = .555$, $p < .001$.

Separate linear regression analyses revealed that children's age was a significant positive predictor of all option-generation and most decision-making variables, except for dynamic inconsistency ($R^2 = .02$, $p = .138$). The older the children, the more options they generated ($R^2 = .06$, $p = .019$, $\beta = .24$), and the higher was the quality of the first option generated ($R^2 = .19$, $p < .001$, $\beta = .44$) as well as that of the option selected as the best ($R^2 = .10$, $p = .002$, $\beta = .31$).

Time Limitation Effects

To explore whether and how *time limitation* influenced the option generation and decision making of children, we performed a multivariate analysis of variance (MANOVA) with one within subject factor time limitation (short-time vs. long-time condition) and four dependent variables (number of options generated, quality of the first option, quality of selected option and dynamic inconsistency). The repeated-measures MANOVA showed a significant multivariate effect, Wilks's Lambda $\lambda = .20$, $F(5, 92) = 34.50$, $p < .001$, $\eta_p^2 = .62$. Follow-up univariate effects were further inspected for each decision-making variable separately.

In the short-time condition, as compared to the long-time condition, children generated fewer options, $F(1, 96) = 127.51$, $p < .001$, $\eta_p^2 = .57$, generated first options with higher quality, $F(1, 96) = 15.19$, $p < .001$, $\eta_p^2 = .14$, and selected options of higher quality as their final, best decisions, $F(1, 96) = 16.55$, $p < .001$, $\eta_p^2 = .15$. With shorter time, dynamic inconsistency was less apparent than in the long-time condition, $F(1, 96) = 14.39$, $p < .001$, $\eta_p^2 = .13$.

Table 1: Effect of time limitation on the considered option generation and decision making variables.

	Short-time condition		Long-time condition	
	M	*SD*	*M*	*SD*
Total number of options	1.84	0.56	2.59	0.86
Quality of first option	4.99	1.32	4.45	1.09
Quality of final decision	4.75	1.34	4.16	1.21
Dynamic inconsistency	0.22	0.20	0.29	0.21

Children generated their first option in a meaningful way: in the short-time condition, Greenhouse-Geisser corrected $F(2.35, 225.77) = 567.40$, $p <.001$, $\eta_p^2 =.86$, and in the long-time condition, $F(3.09, 296.81) = 489.89$, $p <.001$, $\eta_p^2 =.84$, a significant decline of option quality across the serial position was apparent. Most importantly, children selected their first option to be the final decision in 71.1% ($n = 621$) of the decisions in the long-time condition and significantly more often in 77.8% ($n = 679$) of the decisions in the short-time condition, $\chi^2(1, N = 97) = 11.60$, $p = .001$, $r = .16$.

In both conditions, the first option generated was selected to be the final decision more frequently, in the short-time, $\chi^2(5, N = 97) = 1982.61$, $p < .001$, $v = .67$, and in the long-time condition, $\chi^2(5, N = 97) = 2444.15$, $p < .001$, $v = .75$. For both time-limitation conditions, children's decision making was more dynamically inconsistent the more options they generated (short-time condition: $r = .448$, no time limitation: $r = .581$). Further, separate linear regression analyses were conducted for each time-limitation condition. Results revealed that the total number of options children generated predicted the degree of dynamic inconsistency in both conditions: The more options children generated in the short-time, $\beta = .58$, $t(95) = 6.95$, $p < .001$, $R^2 = .33$, or in the long-time condition, $\beta = .45$, $t(95) = 4.88$, $p < .001$, $R^2 = .19$, the more dynamic inconsistent were their decisions.

We tested further whether age was differentially predictive when time is limited. In the short-time condition, children's age was a significant positive predictor of all option-generation and most decision-making variables, except for dynamic inconsistency ($R^2 = .01$, $p = .245$, $\beta = .12$). With time limitation, the older the children, the more options they generated ($R^2 = .11$, $p = .001$, $\beta = .33$) and the higher the quality of the first option generated ($R^2 = .13$, $p < .001$, $\beta = .36$) as well as that of the option selected as best ($R^2 = .10$, $p = .002$, $\beta = .31$). For the long-time condition, no age effect was found on the number of options generated ($R^2 = .02$, $p = .153$, $\beta = .15$), the quality of the final option selected as best ($R^2 = .04$, $p = .057$, $\beta = .19$) and on dynamic inconsistency ($R^2 = .02$, $p = .130$, $\beta = .16$), but the older the children the higher the quality of the first option in the short-time condition ($R^2 = .13$, $p < .001$, $\beta = .36$).

Discussion

Little, if anything, is known about how children generate options about which actions can be taken in real-life situations. To address this question, we tested the option generation and decision making of children based on the predictions of the TTF heuristic. In addition, the influence of time limitation on option generation and decision making was explored. This allowed deepening our understanding of the adaptive relation between time limitation as one relevant environmental factor and the decision-making process predicted by TTF heuristic as argued from an ecological rationality perspective. In an experiment, children between the age of six and 13 years were tested in a video-based soccer decision-making task involving a within-subject time-limitation manipulation.

First, we investigated children's (6- to 13-year-olds) *option generation* process for the first time. Testing the TTF model revealed that predictions of the TTF heuristic also hold for children. In the option generation phase, as expected, children generated between two and three options, did so in a meaningful, non-random way and selected their first option as the final decision in more than 50% of the cases. Further, children's option generation influenced their decisions making: the more options children generated, the more dynamically inconsistent they decided. The pattern of results in children mainly matches option-generation and decision-making processes that have previously been demonstrated in adolescents and adults (Belling et al., 2015; Johnson & Raab, 2003). The results are also consistent with findings showing that already schoolchildren use decision heuristics that match the task at hand (e.g., Horn et al., 2016).

Second, we explored whether and how *time limitation* influenced the option generation and decision making of children. Because of its naturally occurring dynamics, the sports domain is the ideal testbed to investigate situational, real life influence like time limitation. Our results revealed that time limitation affected all decision-making variables. In response to limited time, children generated fewer options, were less inconsistent in their decisions, generated higher quality first options and selected higher quality options as final decisions. This last result differs from what found with adult soccer players, whose quality of option generation and selection was not enhanced in response to time limitation (Belling et al., 2015). However, the positive effect of time limitation on children's option quality demonstrated in the present study theoretically matches predictions of the TTF heuristic and fits with the ecological rationality perspective (Johnson & Raab, 2003; Todd et al., 2012). Compatible with the notion of "less-is-more", the time constraint prompted the generation of fewer but better options. Our results are also consistent with studies demonstrating that children are indeed ecological learners and speak for an adaptation of strategy use to the situation or task at hand (Horn et al., 2016; Ruggeri & Lombrozo, 2015).

Finally, we found consistent developmental effects on both option generation and decision making: The number of options generated increased with age, but only in the short-time condition. This short-time specific age effect hints at a developmental advantage for older children. With increasing age, children seem to adapt to time limitation by speeding up their generation to still produce a valid amount of options they can choose from ($M(SD)_{\text{time limitation}}$ = 2.00 (0.46)), whereas younger children do not ($M(SD)_{\text{time limitation}}$ = 1.67(0.60)). In addition, older children seem to focus more on relevant, high-quality options early in the generation, irrespective of time limitation. This was indicated by the quality of the first option generated increasing with children's age irrespective of time limitation. In line with results showing that the information-search behavior of younger children (7- to 10-year-olds) was not more selective (Davidson, 1996), this study showed that selectivity for high-quality information during generation seems to emerge later in childhood. For the quality of the final decision, as for the number of options, an increase with age was only apparent under limited time. This could be interpreted as a stronger adaption to time limitation by applying a strict, selective decision rule or applying it, according to the TTF heuristic, more accurately (Johnson & Raab, 2003). Summing up, we showed that children adapted to the situational demands of time limitation by relying more on the simple TTF heuristic.

In conclusion, the present study shows that in familiar situations children tend to use simple, intuitive option generation and decision-making strategies. In particular, results support that TTF as a cognitive model can account for the option generation and decision making of children between the age of six and 13 years. Further, the study indicates that time limitation was an important situational factor impacting children's decision-making processes. Future studies should, therefore, explore other potentially relevant situational factors. Deepening our understanding of environmental or situational influences would also provide a concrete anchor for interventions targeting children's options and choices. Dynamic decision environments could, for example, be manipulated by the speed, distance or amount of stimuli provided. In particular, effects of situational factors on children's decision-making processes could be integrated into computer-based or real-life interventions and tested in a randomized control trial. Based on that, knowledge should be incorporated into prevention (e.g. traffic education) and training (e.g., sports, physical education) programs in a second step.

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