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A Developmental Perspective on Option Generation and Selection

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Little is known about how children generate options for taking action in familiar situations or how they select which action option to actually perform. In this article, we explore the interplay between option generation and selection from a developmental perspective using sports as a testbed. In a longitudinal design with four measurement waves, we asked 6- to 13-year-old children ($N = 73$) to generate and select action options in a soccer-related task. Children generated and selected options in accordance with the predictions of the take-the-first heuristic, which served as a theoretical starting point: They generated only a few options in decreasing order of validity (i.e., better options were generated earlier) and selected the first options they had generated. Older children selected the first option generated more often than younger children and generated options faster. Longitudinal effects revealed that both age groups generated fewer options and faster across waves. Time limitation fostered fewer and higher quality options being generated and selected. Overall, our results highlight the importance of considering the predecisional process of option generation to deepen our understanding of developmental changes in decision-strategy use. Future research directions and implications for children's real-life decision making are discussed.

Keywords: option generation, option selection, take-the-first heuristic, decision making, cognitive development

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Imagine being a young, talented soccer player. You are running through the midfield toward the goal, dribbling past one opponent after another. You are now 20 m from the goal, facing the opposing defense rapidly closing on you. What could you do? Shoot at the goal from where you are? Or should you pass the ball to one of your teammates—maybe the one approaching from the left? Making good and quick decisions is essential in sports, as in many other domains (Raab & Gigerenzer, 2015). Most often in real life, before actually deciding what to do, one has to think about what could be done, generating and simulating alternative actions that could be taken and imagining how possible scenarios could be played out.

Little is known about how decision-making strategies develop across childhood, and even less—if anything—is known about how children generate action or decision options and select among them. In this article, we explore for the first time the interplay between option generation and selection, crucial building blocks of decision making, from a developmental perspective, using sports as a testbed.

Children's Decision Making

Despite the increasing interest in the study of decision making, most previous research has focused either on adults or on the aging decision maker (Horn, Pachur, & Mata, 2015; Mata et al., 2012; Mata, Schooler, & Rieskamp, 2007). Indeed, only a few studies have explored the development of decision-making strategies across childhood (Klaczynski, 2001). In particular, decision-making research with children has focused on predecisional information search (i.e., the information children spontaneously ask for;

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see Ruggeri & Katsikopoulos, 2013; Ruggeri, Olsson, & Katsikopoulos, 2015; or the information children select from a set of informational items; see Davidson, 1991, 1996; Gregan-Paxton & Roedder John, 1995; Lindow & Betsch, 2018) or has investigated cue-based decision strategies (Betsch, Lehmann, Lindow, Lang, & Schoemann, 2016; Horn, Ruggeri, & Pachur, 2016; Mata, von Helversen, & Rieskamp, 2011). It has been shown, across a wide range of inference tasks (e.g., "Which of these two cars is more expensive?"), children tend to generate more predictive cues than adults (Ruggeri et al., 2015), possibly because they do not filter out the less relevant and predictive cues, as adults tend to do. Along the same lines, previous studies implementing a cue-selection paradigm found that younger children (7 to 9 years old), compared with older children (10 to 12 years old) and adults, tended to search for more irrelevant information (Davidson, 1991), preferred more information-intensive strategies (e.g., strategies that collect and integrate all the information available), and had a harder time focusing on one or a few most informative cues when making decisions (Lindow & Betsch, 2018; Mata et al., 2011). Similarly, a recent study by Betsch and colleagues (2016) showed that neither preschoolers' nor primary schoolchildren's search was guided by the informativeness of the given cues. On the basis of these studies, it has been concluded that, with age, children rely on simpler strategies, because they become able to selectively focus their attention on the most relevant and inhibit inappropriate or irrelevant information.

To our knowledge, *option generation*, that is, the process of generating alternative action or decision options from which to select (Johnson & Raab, 2003), has never been studied in children before. How many options do children generate and consider before making a selection? How good are those generated options, and are they generated in a random fashion or is the generation process systematic? Children start at an early age to make decisions when they need to consider alternative options: what food to buy at the school canteen, what game to play, what club or hobby to commit to, what way to walk to school. Understanding the way children come up with and select alternative actions or decision options can shed light on the development of their decision-making strategies. We consider the development of decision-making strategies from an ecological rationality perspective (Todd, Gigerenzer, & the ABC Research Group, 2012). Within this framework, strategies are not good or bad per se, but rather, their effectiveness depends on the cognitive abilities of the decision-making agent, as well as on the characteristics of the environment considered. Thus, when studying the developing decision maker, it is crucial to consider "the individual and [his or her] particular stage of ontogenetic development" (Todd et al., 2012, p. 11) also because the developmental stage influences the effect a given environment has on a person's use of heuristics (Marasso, Laborde, Bardaglio, & Raab, 2014). In line with the theoretical notion of ecological rationality and the empirical evidence from developmental studies reviewed above, we expect older children to be more likely than younger children to rely on a simple decision strategy.

Option Generation and the Take-the-First (TTF) Heuristic

A decision-making strategy usually consists of a search, a stop, and a decision rule, which together define how and how much information has to be collected before one can make a decision (Gigerenzer, Todd, & the ABC Research Group, 1999). However, most real-world situations require people to generate alternative options before making a decision, rather than selecting one from a set of predefined options offered by an experimenter (Payne, Bettmann, & Johnson, 1988). Option generation has previously been studied with adults and adolescents in sports (Johnson & Raab, 2003; Raab & Johnson, 2007). Indeed, because of its naturally occurring dynamics (e.g., decisions to be made under time pressure; many potential alternative actions to be considered), sports is the ideal domain to test whether people use fast-and-frugal heuristics, such as the TTF heuristic (Raab, 2012; Raab & Gigerenzer, 2015).

The TTF heuristic 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). The building blocks of TTF are formally defined as follows: a *search rule,* which generates options in order of validity (i.e., better options generated earlier), so that subjectively better options are generated earlier; a *stop rule,* according to which the generation phase should stop after two or three options have been generated; and a *decision rule,* according to which people should select one of the initial options generated (Johnson & Raab, 2003). Following TTF, people would generate only a few options and select the first one generated, rather than exhaustively generating and processing all possible options. Because these options were generated in order of validity, the decision, although fast and frugal, would tend to be accurate. Empirical studies have shown that the performance of experienced handball (Johnson & Raab, 2003), basketball (Hepler & Feltz, 2012), and soccer (Belling, Suss, & Ward, 2015) players is quite accurately predicted by the TTF heuristic: Players generated about two options (e.g., shoot at the goal or pass to a teammate) in order of validity and selected the first option generated as the final decision. Importantly, effects of expertise on option generation, and, in particular, on the implementation of the TTF heuristic have also been evident in previous work. For example, handball experts generated fewer options (Laborde & Raab, 2013; Raab & Johnson, 2007) and selected the first option as final decision more frequently (Laborde & Raab, 2013) than near-experts. Thus, the predictions of the TTF heuristic with respect to the search, stop, and decision rule can serve as a starting point to examine option generation and selection in children in a sports task they are familiar with.

Time-Limitation Effects on Option Generation and Decision Making

According to the ecological rationality framework (Todd et al., 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. In many real-life situations, as in sports, decisions have to be made under limited time, and adults have been shown to adapt to time limitation by using faster and simpler strategies (Ben Zur & Brenitz, 1981; Payne et al., 1988). Along the same lines, 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 the performance of developing decision makers? We know that children are *ecological learners*—that is, they 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 the age of 4 years (Ruggeri, Sim, & Xu, 2017). However, Davidson (1996) investigated the influence of time limitation on children's (7 to 10 years old) information-search behavior and found that time limitation promoted faster, but generally not more selective searching.

The Present Study

In the present study, we examined the development of children's option generation and selection by testing 6- to 13-year-old soccer players. The longitudinal study was embedded within a larger cooperation project on the development of young expert soccer players with a first division soccer club, in which additional measures including general physical measures (i.e., weight, height, grip strength), general cognitive measures (i.e., trail making, task switching, cognitive ability) and self-report questionnaires (i.e., motor reinvestment, preference for intuition and deliberation, self-efficacy, soccer-specific self-efficacy, sports orientation, soccer-specific experience) were assessed (Musculus, 2018; Musculus, Raab, Belling, & Lobinger, 2018). We assumed the participants to be familiar with the option-generation and selection task administered, because they are used, during training, to watch their and their peers' performance on videos, as a way to provide and receive feedback and comments. In particular, we investigated how well children's option generation (search and stop rules) can be described and predicted by the TTF heuristic. Additionally, we tested the decision rule of TTF against other decision models: the random selection model, where the action to perform is selected randomly from the set of generated options; the take-the-best-option (TBO) heuristic, which predicts that children will select the best option (i.e., the option with the highest quality) among those generated; and the take-the-last (TTL) heuristic, which predicts the selection of the option generated last. By comparing TTF with these models, we test directly the effects of option quality and serial position (i.e., order in which the options have been generated) on the final decision.

The rationale for the present study is rooted in theoretical work and empirical evidence derived from both developmental psychology (Bereby-Meyer, Assor, & Katz, 2004; Betsch et al., 2016; Davidson, 1991; Marasso et al., 2014; Mata et al., 2011; Ruggeri & Katsikopoulos, 2013) and research on cognitive expertise in sports (Johnson & Raab, 2003; Laborde & Raab, 2013; Raab & Johnson, 2007). As children have been shown to use simple, noncompensatory information-search strategies (Bereby-Meyer et al., 2004; Ruggeri & Katsikopoulos, 2013) and adolescent handball players have been shown to act according to TTF (Johnson & Raab, 2003), we expected children to make use of the TTF heuristic in a familiar task. Taking into account previous developmental studies showing an increase in selective, noncompensatory strategy use with age (Davidson, 1991, 1996; Mata et al., 2011) and expertise studies indicating that experts as opposed to near-experts used TTF more often (Laborde & Raab, 2013), we also expected older children to be more likely than younger children to rely on the TTF heuristic.

Whereas previous research has mainly used cross-sectional designs, in the present study we implemented a longitudinal design similar to that of Raab and Johnson (2007) allowing us to monitor strategy change over time. We expected children to increase their reliance on fast-and-frugal heuristics across waves as they gained more experience (cf. Raab & Johnson, 2007). More precisely, with a focus on the individual building blocks of the TTF, we predicted that children would generate options faster (search rule; Raab & Johnson, 2007) and would generate fewer options (stop rule) across waves (see Laborde & Raab, 2013; Raab & Johnson, 2007). Whether children would select the first option as their final choice more often across waves (decision rule) is more difficult to predict: Although theoretically an increase in experience should lead to selecting the first option more often as the final choice (Johnson & Raab, 2003; Raab & Johnson, 2007), no changes were found in the longitudinal study with adolescents (Raab & Johnson, 2007). Moreover, considering the general information-search literature that shows a developmental increase in the ability to ignore irrelevant information to focus on the most informative cues (Davidson, 1991; Gregan-Paxton & Roedder John, 1995; Mata et al., 2011), as well as previous work showing a more frequent selection of the first option as final decision with increasing expertise (Laborde & Raab, 2013), we expected children to generate and select higher quality options across waves.

Finally, we explored whether and how time limitation influences children's option generation and selection. From the literature reviewed above it is unclear whether and how children would adapt their option generation and selection depending on the time available.

Method

Participants

A total of 98 boys, recruited from a professional soccer academy in Germany, participated in this study. Using G-Power sample size estimation (Faul, Erdfelder, Buchner, & Lang, 2009), we estimated needing a sample of 66 participants (α = .05, 1 – β = 0.80, f = 0.42, in the study of Belling et al., 2015). We recruited 98 participants to account for an expected dropout rate of about 25% across waves (cf. longitudinal study by Raab & Johnson, 2007). Of the original sample, 73 completed all four measurement waves and were consequently included in the analyses: 38 younger children belonging to the under 11 teams (M = 8.73 years, SD = 1.15 years; range = 6.67–10.50 years) and 35 older children belonging to the under 14 teams (M = 12.37 years, SD = 0.81 years; range = 10.92–13.50 years).

Most children (n = 65, 90%) were German; all children were German speaking and lived in or near a large city in Western Germany. Before the start of the study, written informed consent was obtained from participants' parents and the local ethical review board at the German Sport University approved the study protocol for the project ("Development of Soccer-Specific Decision Making," Number 99/2015).

Materials

We used 21 video scenes of live soccer match footage (three for the practice trials, 18 for the test trials). Video-based stimuli have been reported to be superior for assessing children's decision making, as opposed to other kind of stimuli such as abstract representations of situations (Marasso et al., 2014). We selected these specific video trials, because they have been shown to provide a large option space for adult soccer players (cf., Belling et al., 2015). To ensure that the video trials contained a large enough space of potential options also for children, we asked two additional expert youth coaches and 13 young soccer players (M_{age} = 10.60, SD_{age} = 0.60) to generate as many options as possible for each of the presented video scenes. We found that an average of 5.50 different options (SD = 1.93) per video were generated. The experts generated a mean of 7.94 (SD = 1.88) and the young soccer players generated a mean of 5.12 (SD = 1.16) options. For the average number of options generated for each video trial, see Table S1.1 in the online supplemental material.

We administered the video trials through a temporal-occlusion paradigm, adopting the same materials and a similar task as in Belling et al. (2015): After a short display of buildup play, the scenes suddenly stopped with a frozen frame, right before the player in possession of the ball had to make a decision (see Figure 1). We chose this particular decision-making task because it is the paradigm previously used to assess option generation and selection (Belling et al., 2015; Hepler & Feltz, 2012; Johnson & Raab, 2003; Raab & Johnson, 2007). Materials were presented to children on an 8.9-in. tablet.

Design and Procedure

We conducted the present study in a longitudinal cohort design (Schaie & Baltes, 1975), in which two age groups of children were tested in four waves at intervals of 6 months (referred to as t1 through t4; Wave 1: August 2015; Wave 2: February 2016; Wave 3: August 2016; Wave 4: February 2017). Overall, the study included three factors: measurement wave (four levels: t1–t4) and time limitation (two levels: short- or long-time condition) as within-subject factors and age group (two levels: younger or older children) as between-subjects factor, resulting in a 4 × 2 × 2 design. We considered age as a discrete variable because in the professional youth academy players belong to two different age-related training departments, namely Youth Development (under 14 teams) and Foundation (under 11 teams). Thus, the age groups in the present study reflect the natural grouping of the players.

The task was administered to groups of five to nine same-aged children in a quiet room located at the soccer academy. Children, sitting alone at individual desks where a tablet was positioned, were introduced to the task procedure via a standardized instructional video (duration: 2:51 min) that was meant to familiarize them with the tablet and the task by walking them through the testing procedure. The experimental session consisted of 21 trials. The same trials were used across waves to experimentally control the option space, as in Raab and Johnson (2007): The first three were practice trials, where children could ask the experimenter to clarify any questions. Only the results of the 18 test trials were included in the analyses. Each trial comprised two phases: option generation and option selection.

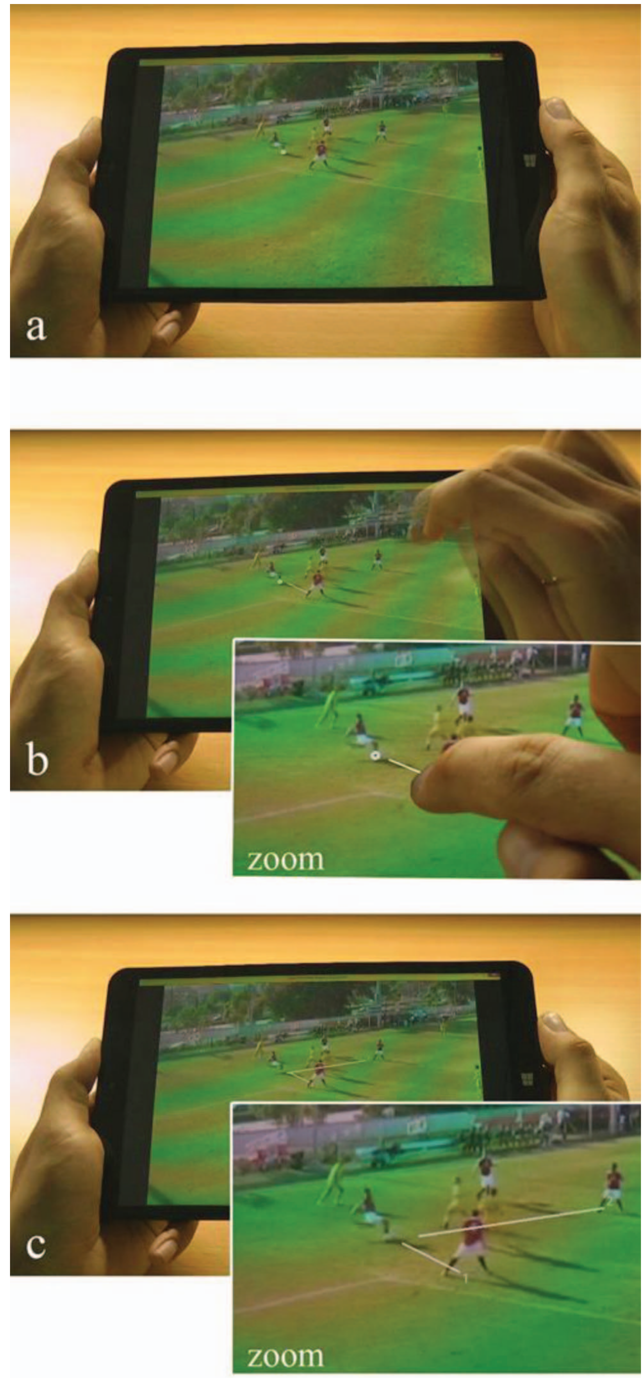

Figure 1. Option-generation and selection procedure. (a) After a short display of buildup play, the scene stopped with a frozen frame, right before the player in possession of the ball had to decide which action to take. (b) Children generated alternative actions the player in possession of the ball could take by drawing them on the screen. (c) Children reviewed their generated options and selected the one they thought was the best. Adapted from "Do the Best Players 'Take-the-First'? Examining Expertise Differences in the Option-Generation and Selection Processes of Young Soccer Players," by L. Musculus, 2018, *Sport, Exercise, and Performance Psychology, 7,* p. 276, Copyright 2018 by APA. Adapted with permission. See the online article for the color version of this figure.

Option generation. On each trial, children were presented with a video of buildup play that stopped and held on a frame (see Figure 1 and the Materials section). Children were then asked to generate *good* action options, directly marking them on the field using the touch screen (see Figure 1a and 1b). Children could generate a maximum of six different options (e.g., pass to the player on the right; dribble; shoot). Trials were randomly assigned to either the short-time (nine trials) or the long-time (nine trials) condition. In the long-time trials children were given 30 s to generate options, whereas in the short-time trials they were given 7.5 s to generate options. The order of presentation of the test trials was randomized.

Option selection. Children were presented with the action options they had generated in the previous phase and were asked to select the best option among these (see Figure 1c).

Coding

To assess the quality of the options generated and selected, two experienced youth soccer coaches, blind to the experimental hypotheses, independently evaluated the options the children had generated for the 18 test trials. Both coaches had a UEFA B-level coaching license and at least 10 years of experience coaching a youth soccer team. For each of the 18 test trials, presented in random order, coaches were asked to rate the options on a 10-point scale (1 = *not at all good* to 10 = *very good*). Having obtained good interrater agreement for the best option (Krippendorff's κ = .82, p = .01, intraclass correlation coefficient [ICC] = .77, $p <$ .001) and quality of all options generated (r = .56, p = .01, ICC = .67, $p < .001$), we computed the quality scores for each generated option by averaging coaches' quality ratings.

Results

First, for the 73 participants who completed all measurement waves, we performed separate, stepwise linear mixed-models analyses to investigate the effects of age group (two levels: younger vs. older children) as a between-subjects variable and wave (four levels: t1, t2, t3, t4) and time limitation (two levels: short-time vs. long-time) as within-subjects variables on four outcomes: (1) mean number of options generated across the 18 test trials; (2) average time taken to generate the first option; (3) average quality across all the generated options; and (4) average quality across all the selected options.[1] Second, we interpreted the results in light of the predictions of the TTF heuristic, further comparing them against predictions of the random selection model, the TBO heuristic, and the TTL heuristic.

Option Generation

Number of options generated. Pooling across participants, children generated a mean of 3.5 *unique* options per video trial (3 in the short-time and 4 in the long-time condition). Overall, in line with the TTF, children stopped their generation after a mean of two options (1.92 options, SD = 0.99). In 41.3% (n = 2,125) of all trials, exactly two options were generated and in 35% (n = 1,822) of all trials, only one option was generated. Older and younger children did not differ in the number of trials in which they generated exactly two options (younger children: 33.6%; older children: 49.5%; p = .081). However, a chi-square test showed that older children generated only one option in fewer trials (24%) compared with younger children (45.7%), $\chi^2(1) = 6.47$, p = .011, Cramér's V = 0.30. Also, in 2.1% (n = 111) of all trials no options were generated. Older and younger children did not differ in the number of trials for which they generated no options (younger children: 1.4%; older children: 0.7%; p = .629).

The analysis revealed that the random intercept and slope model including interaction terms resulted in the best model fit for the number of options generated (R^2 = .30). We found no effect of age group (p = .583), but we did find main effects of wave ($B = -0.22$, $p < .001$) and time limitation ($B = -0.75$, $p < .001$) on the number of options generated, as well as a Wave $\times$ Time Limitation interaction (B = 0.14, $p < .001$). In particular, the analysis showed that fewer options were generated across waves (M_{t1} = 2.08, SD = 1.19; M_{t2} = 2.09, SD = 1.00; M_{t3} = 1.80, SD = 0.86; M_{t4} = 1.73, SD = 0.80) and that in the short-time condition children generated fewer options (M_{short} = 1.70, SD = 0.84) than in the long-time condition (M_{long} = 2.15, SD = 1.07). Moreover, the interaction effect revealed that in the long-time condition the number of options generated decreased across waves more dramatically than in the short-time condition, $t(1195) = 9.44$, $p < .001$, d = 0.52 (see Figure 2).

Generation time of the first option generated. The mean generation time of the first option was 741.18 ms (SD = 386.11 ms). The random intercept and slope model without interaction terms showed the best model fit for the generation time of the first option (R^2 = .28). All fixed factors—age group (B = 87.48, p = .024), wave ($B = -42.6$, $p < .001$), and time limitation ($B = -97.59$, $p < .001$)—influenced the generation time of the first option. Older children (M_{older} = 691.70 ms, SD = 351.91 ms) generated the first option faster than younger children ($M_{younger}$ = 786.96 ms, SD = 410.10 ms). Options were generated faster across waves (M_{t1} = 827.29 ms, SD = 446.09 ms; M_{t2} = 735.36 ms, SD = 378.99 ms; M_{t3} = 703.12 ms, SD = 360.48 ms; M_{t4} = 700.19 ms, SD = 338.54 ms) and in the short-time condition (M_{short} = 689.68 ms, SD = 339.75 ms; M_{long} = 790.70 ms, SD = 420.24 ms). No interactions between the fixed factors were apparent.

Quality of the generated options. The mean quality across all generated options was 4.62 (SD = 2.79). For the mean quality of all options, the random intercept and slope model without interaction terms resulted in the best model fit (R^2 = .11). The analysis revealed no effect of age group ($B = -0.14$, p = .623) or wave (B = 0.05, p = .468) but did reveal a main effect of time limitation. The quality of all options generated was higher in the

[1] We performed step-wise, mixed-model analyses for each of the four dependent variables (number of options, option generation time, quality of first option, quality of final option, first option selected as final option) for all 98 participants who participated in at least one session of the study. We obtained the same results, model fits, and effects for all dependent variables as we did for the 73 participants who completed all measurement waves (see S.2 of the online supplemental material). In addition, we performed the same step-wise, mixed-model analyses for each of the four dependent variables with age as a continuous variable. We obtained the same results, model fits, and effects for all dependent variables as we did for age groups, with the following exception: With age as a continuous variable, the wave effect and the Wave $\times$ Time limitation interaction for the number of options generated were not significant.

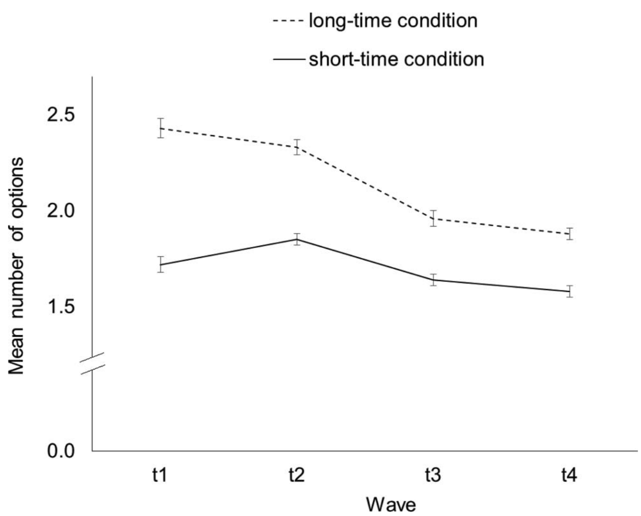

Figure 2. Number of options generated across waves (t1–t4) in the long-time and short-time conditions. Error bars represent one standard error of measurement in each direction.

short-time condition (M_{short} = 5.26, *SD* = 2.79) than in the long-time condition (M_{long} = 4.00, *SD* = 2.65; *B* = 1.3, $p < .001$).

The first option generated had a mean quality of 5.20 (*SD* = 3.48). For the quality of the first option generated, the random intercept model without interactions yielded the best model fit (R^2 = .05). The quality of the first option generated was not affected by age group (*p* = .951) or wave (*p* = .328) but was affected by time limitation (*B* = 1.00, $p < .001$). Overall, children generated options of higher quality in the short-time (M_{short} = 5.71, *SD* = 3.36) compared with the long-time (M_{long} = 4.71, *SD* = 3.53) condition.

As predicted by the TTF, children generated options in order of validity, which was confirmed by a repeated measures analysis of variance (ANOVA). The quality of the first three options generated differed significantly across serial positions, Greenhouse–Geisser $F(1.46, 361.29) = 188.33$, $p < .001$, $\eta_p^2 = .43$: The first options generated were of higher quality (*M* = 5.23, *SD* = 0.93) compared with the second (*M* = 3.60, *SD* = 1.21), $F(1, 248) = 401.96$, $p < .001$, $\eta_p^2 = .62$, and third options (*M* = 2.83, *SD* = 2.07), $F(1, 248) = 315.33$, $p < .001$, $\eta_p^2 = .56$.[2] Children of both age groups generated options in order of validity as no age differences were apparent when considering the interaction with age group (*p* = .557). The same pattern of results was also apparent when each wave was analyzed separately (for the results reported by wave, please refer to the section S3 of the supplemental materials).

Our additional analysis revealed that the more options children generated, the less often their first option generated was the best of all their options, $\chi^2(4) = 317.84$, $p < .001$, Cramér's V = .31. Although children's first option generated was the best in 27.6% of the trials in which two options were generated, this was the case in only 3.4% and 0.5% for three and four options generated, respectively. When five or six options were generated, the first option selected was never the best. The same trend was apparent for both, the younger ($\chi^2(4) = 115.87$, $p < .001$, Cramér's V = .28) and the older age group ($\chi^2(4) = 199.57$, $p < .001$, Cramér's V = .33).

Option Selection

Quality of the selected option. The mean quality of the options selected across trials was 5.00 (*SD* = 3.56). The random intercept and slope model without interaction terms resulted in the best model for the quality of the final option selected (R^2 = .07). Our mixed-model analysis revealed no main effects of age group (*p* = .592) or wave (*p* = .231) on the quality of the final option selected. However, we found a main effect of time limitation (*B* = 0.79, $p < .001$): Children selected options of higher quality in the short-time (M_{short} = 5.39, *SD* = 3.51) compared with the long-time (M_{long} = 4.60, *SD* = 3.56) condition.

First option generated selected as final option. Overall, children selected the first option they had generated as their final option in 75.9% of all trials and in 62.7% of trials in which more than one option was generated. Children selected options they had generated at earlier serial positions, particularly their first option generated, more often compared with options generated later in the generation phase (for all trials: all Cramér's V > .68; for trials with more than one option generated: all Cramér's V > .59). Generally, as predicted by the TTF decision rule, children selected the first option generated in more than 50% of the trials (for all trials: all Cramér's V > .43; for trials with more than one option generated: all Cramér's V > .22) and did so less often, the more options they generated ($r < -.38$, all $p < .001$; see Table 1).

Considering only those trials in which more than one option was generated, the random intercept and slope model without interaction terms resulted in the best model fit for the first option selected as final option. The analysis revealed that neither wave (*p* = .770) nor time limitation (*p* = .694) had a significant impact on whether children selected the first as final option, but age group did (odds ratio [*OR*] = 0.6, $p < .001$). Older children (M_{older} = 67%, *SD* = 47%) selected the first as final option significantly more often compared with younger children ($M_{younger}$ = 57%, *SD* = 50%).

We further explored the effect of age group with a series of post hoc analyses. In addition to the fixed effects of wave, time limitation and age group, we controlled for the quality of the first, second and third option. These additional analyses revealed that whether players selected the first option was significantly predicted by the quality of the first (*OR* = 1.09, $p < .001$) and second option (*OR* = 0.93, $p < .001$) but not by the quality of the third option (*OR* = 0.97, *p* = .145) generated, whereas the effect of age group still held (*OR* = 0.67, *p* = .023).

Model comparison. Considering only those trials in which more than one option was generated, children selected the best (i.e., highest quality) among the generated options (TBO heuristic) in 24.4% of the trials. In 18.6% of the trials, taking the best option meant following the TTF decision rule; in 5.8% of the trials, children selected the best but not the first among their options generated, and in 44.1% of the trials, they selected the first but not the best option. Children selected their last option in 27.5% of the trials. Selection of the last option never corresponded to the TTF decision, by definition.

Overall, children selected the first option more often compared with what was predicted by the random selection model,

[2] To avoid the problem of too many missing data points invalidating the results of the ANOVA, we considered only those trials in which a maximum of three options were generated (93%).

Table 1
Absolute Frequency of Selected Options Displayed by Serial Position and Number of Generated Options

Number of generated options	Serial position of the selected option						Total
	1	2	3	4	5	6	
1	1,822	0	0	0	0	0	1,822
2	1,461	664	0	0	0	0	2,125
3	472	223	190	0	0	0	885
4	110	31	27	45	0	0	213
5	26	11	9	8	8	0	62
6	14	7	3	4	2	8	38
Total $n_{\text{all trials}}$	3,905	936	229	57	10	8	5,145
Total $\%_{\text{all trials}}$	75.9%	18.2%	4.5%	1.1%	.2%	.2%	100.0%
Total $n_{\text{trials in which more than one option was generated}}$	2,083	936	229	57	10	8	3,323
Total $\%_{\text{trials in which more than one option was generated}}$	62.7%	28.2%	6.9%	1.7%	.3%	.2%	100.0%

$t(3,322) = 23.78$, $p < .001$, $d = 0.41$; the TBO model (24.4%), $\chi^2(1) = 559.08$, $p = .003$, Cramér's V = .43; and the TTL model (27.5%), $\chi^2(1) = 455.04$, $p = .001$, Cramér's V = .39. See Tables S3.1 and S3.2 in the online supplemental material for the results of the model comparison reported by wave.

In an additional exploratory analysis, we tested whether an increasing number of options generated decreased the likelihood of selecting the first, best, and last option. Results showed that the more options children generated, the less often they selected their first, $\chi^2(4) = 99.90$, $p < .001$, Cramér's V = .17, best, $\chi^2(4) = 452.40$, $p < .001$, Cramér's V = .37, and last option, $\chi^2(4) = 42.83$, $p < .001$, Cramér's V = .11. The same pattern emerged for both age groups. Irrespective of the number of options generated, older children selected the first option generated when it was the best one more often (21.4%) than younger children (15.4%), $\chi^2(1) = 17.50$, $p < .001$, Cramér's V = .07.

Discussion

Little is known about how children generate and select options for taking action in real-life situations. In this article, we explored the interplay of option generation and selection, crucial building blocks of decision making, from a developmental perspective, testing children in a sport-specific task. In particular, taking an ecological rationality perspective, we tested whether the TTF heuristic could predict children's option generation and selection better than other cognitive models.

Children Use the TTF Heuristic

Our results showed that children's option generation and selection were generally well described by the predictions of the TTF heuristic: They generated on average about two options per trial and generated them in a meaningful way, that is, producing higher quality options first. That children did apply the TTF heuristic in a familiar decision-making task is consistent with findings showing that even school-aged children use decision heuristics that match the task at hand (e.g., Horn et al., 2016) and results demonstrating children's use of simple, noncompensatory information-search strategies (Bereby-Meyer et al., 2004; Ruggeri & Katsikopoulos, 2013).

Children's option generation influenced their final selection: For both younger and older children, the more options they generated, the less often they selected the first option. This pattern, that is, the mismatch between the first option generated and the one selected, has been referred to as *dynamic inconsistency* and has been shown to increase with the number of options generated (Johnson & Raab, 2003; Raab & Johnson, 2007). Thus, our results indicate that the decision rule children apply depends, at least to some degree, on their stop rule, such that children's decisions are more dynamically inconsistent when they stop later, after having generated more options. Recent research has identified the stop rule as a crucial factor responsible for younger children's general lower efficiency in information search compared with that of adults (Ruggeri, Lombrozo, Griffiths, & Xu, 2016). On the same line, in the present study children were more efficient when they had generated fewer options: The more options younger and older children generated, the less likely they were to select the first or the best option. Importantly, children's first option selected was also less likely to be the best the more options they had generated, which was true for younger and older children alike. Future research should investigate more systematically children's reliance on the TTF heuristic by manipulating the dominance structure and the size of the option space.

That children do indeed use the TTF heuristic was further supported by our model comparisons: Children's selection was more consistent with the predictions of the TTF, compared with the random, TBO, or take-the-last models. Importantly, children selected the first option in most of the decisions made. Future studies could relate the TTF to other classes of heuristics, by testing it against other cognitive models such as the recognition-primed decision model (Klein, Wolf, Militello, & Zsambok, 1995). To better understand the cognitive mechanisms underlying the developmental change in the decision-making processes, the building blocks of the TTF heuristics could also be tested using a cognitive-modeling approach (e.g., multinomial processing trees; see Horn et al., 2016).

Although the number and quality of options generated did not differ between age groups, older children generated options faster. As hypothesized, older children selected the first option generated more often than younger children. These results can be interpreted as an indication of older children having a stronger and more selective decision rule and are in agreement with previous findings showing that preschoolers and elementary schoolchildren are not yet able to selectively attend to the most relevant information (Betsch et al., 2016; Mata et al., 2011). The results further document a shift to a more pronounced use of noncompensatory strategies by the age of 11 years (Mata et al., 2011). Importantly, our results underline that following the simple decision rule by "taking the first" did not always yield to selecting the best option. Indeed, selecting the first option did not lead children to select the best option in many (44.1%) of the trials. Finally, although no age differences emerged for the quality of the options generated or selected, we observed that older children selected their first option generated when it was the best one more often (21.4%) than younger children (15.4%). In this sense, our results suggest that older children's option generation and selection strategies are more effective than those of younger children.

Longitudinal Effects on Option Generation

Like the adolescent handball players in the study of Raab and Johnson (2007), children of both age groups in the present study sped up their option generation and generated fewer options across the four measurement waves. However, the quality of the options generated and selected was not affected by wave. Contrary to our predictions, children did not select the first option generated more often across waves and, more generally, seemed not to modify their decision rule in the course of the 1.5-year testing period. This result can be interpreted in at least two different ways, not mutually exclusive. First, the gain in domain-specific experience across waves was not enough to shift the decision rule application (Horn et al., 2016; Raab & Johnson, 2007). In this sense, children's experience across waves might not have been enough for them to learn how to implement more effective selection strategies, also because no feedback was offered. Second, there might have been a ceiling effect: Because the children were already selecting the first option generated at a high percentage in the first measurement wave, the potential to increase their reliance on this decision rule across waves was limited.

Future research might try to identify the cognitive mechanisms and developmental factors responsible for the developmental changes observed and sources of individual differences, such as the selective focus of attention or inhibition (Betsch et al., 2016; Lindow & Betsch, 2018; Mata et al., 2011), working memory span, or math skills that could mediate the ability to weight and integrate cues (see Lindow & Betsch, 2018). Methodologically, different video stimuli could be used to test the robustness of the effects obtained in the present study, generalizing to other sports and potentially to other every-day life domains (Kaiser et al., 2013).

Time Limitation Fosters Better Options and Decisions

In contrast with the results obtained with adult soccer players (Belling et al., 2015), when less time was available, children generated fewer options and selected options of higher quality. Indeed, in line with the notion of "less-is-more" and in theoretical agreement with the ecological rationality perspective (Johnson & Raab, 2003; Todd et al., 2012), the time constraint prompted the generation of fewer but better options. More generally, our results speak to children's ecological learning, that is, to their ability to adapt their decision strategy to the situation or task at hand (Ruggeri & Lombrozo, 2015; Ruggeri et al., 2017).

Interestingly, an interaction of time limitation and wave also emerged: In the long-time condition the number of options generated decreased across waves more dramatically than in the short-time condition. Although children generated fewer options in response to short time at all waves, in the long-time condition children adapted their stop rule across waves, eventually converging on the number of options generated in the short-time condition. This indicates that children learned, across waves, to constrain themselves during generation even though time was available to generate more options, becoming more selective. This result also suggests that children internalized the effectiveness of generating fewer, high quality options.

Conclusions

The present study shows that 6- to 13-year-old children generate and select options as predicted by the TTF heuristic. Importantly, developmental differences were evident for the decision rule: Older children selected the first option as their final choice more frequently than younger children. Future research should test whether, as we believe is the case, our results generalize to a broader range of dynamic decision tasks children have experience with.

More work is needed to investigate how the interaction of developmental and environmental factors can impact children's predecisional and decisional processes (Marasso et al., 2014; Mata et al., 2012). In particular, it is crucial to understand which and how individual and age-related differences, such as the ability to selectively focus on relevant information or effective information integration (as discussed by Mata et al., 2011) and cognitive flexibility (e.g., task switching; Best & Miller, 2010; Legare, Mills, Souza, Plummer, & Yasskin, 2013), may affect option generation and selection. On the other hand, future research should also investigate how different characteristics of dynamic everyday situations, such as traffic conditions, impact children's option generation and selection. Systematically manipulating environmental constraints across computer-based or real-life tasks will shed light on children's ability to adapt their decision-making strategies in real time. What is learned could inform the development of age-tailored interventions focusing on prevention (e.g., traffic education) and training (e.g., sports, physical education).

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