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Fast or Accurate? The Change of Goals Modulates the Efficiency of Executive Control

Abstract: *In the present study, we analyse the influence of goal maintenance and goal change on the efficiency of executive control. Although there is empirical evidence on the impact of goal maintenance and task-switching on executive control, little is known about the consequences of changing between processing goals (e.g., speed or accuracy goals). We assessed the influence of changing between speed and accuracy goals while performing a task-switching procedure that requires social categorization. Experiment 1 included frequent goal changes, whereas Experiment 2 included one goal change across the experimental session. The results showed that both goals influence general performance and flexibility. A comparison between experiments suggested that frequent goal change (Experiment 1) resulted in worse performance and lower flexibility overall, compared to sequential goal change (Experiment 2). Frequent goal change was also associated with increased difficulties in pursuing the accuracy goal. The implications regarding the role of goal maintenance and goal change on executive control are discussed, as well as new research possibilities.*

Keywords: *executive control, goal maintenance, goal change, cognitive flexibility*

FAST OR ACCURATE? THE CHANGE OF GOALS MODULATES THE EFFICIENCY OF EXECUTIVE CONTROL

Goals represent subjectively desirable states that individuals try to accomplish through action (Kruglanski, 1996). They impact several aspects of human lives, such as academic performance (Morisano et al., 2010; Zimmerman et al., 1992), job satisfaction (Maier & Brunstein, 2001), or habit acquisition (e.g., Wood & Neal, 2007; Wood & Rünger, 2016). Moreover, goals also influence the way individuals process different types of information (e.g., Krajewski et al., 2011; Moskowitz, 2002; Peterman, 1997), and have been shown to affect general cognitive processes, such as executive control (Botvinick & Braver, 2015).

Executive control refers to the superordinate cognitive functions that regulate the expression of our behaviour (for a review, see Jurado & Rosselli, 2007). It includes the update of working memory representations, switching between tasks or mental sets, and the inhibition of prepotent responses (Miyake et al., 2000). The functioning of these cognitive processes has been widely analysed in the field of cognitive science (e.g., Aron et al., 2004; Banich, 2009; Botvinick et al., 2001; Braver, 2012; Koechlin et al., 2003; Ye & Zhou, 2009; Yuan & Raz, 2014). However, although the efficiency of executive control depends on different goal-driven motivations (for a review, see Botvinick & Braver, 2015), little is still known about how these motivational processes interact with executive control. More specifically, what are the motives that prompt executive control, and how these motives affect different aspects of executive control, such as information processing, effort, general performance, or task outcome (Botvinick & Braver, 2015; Locke & Latham, 2002).

The role of motivation in executive control has been studied primarily from a reward-based perspective (e.g., Dixon & Christoff, 2012; Kleinsorge & Rinkenauer, 2012; Westbrook et al., 2013), with the focus on executive

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control tasks that involve selective attention (Padmala & Pessoa, 2011), response inhibition (Leotti & Wagner, 2010), or task switching (Kleinsorge & Rinkenauer, 2012), but the evidence on the impact of other types of motivations is very limited. To understand how executive control influences our behaviour, it is necessary to comprehend how different goals impact executive control, and to grasp not only the impact of a current goal, but also the process of changing goals. This study aimed at analysing the impact of both goal maintenance and goal change on executive control.

The Influence of Goals on Executive Control

The importance of executive control in our lives is undeniable. It regulates basic processes as attention or language, and it coordinates our behaviour towards specific actions (Botvinick & Braver, 2015). Researchers from various fields, including cognitive science, language, memory, neuropsychology, or neuroscience, have studied this topic for decades (e.g., Adrover-Roig et al., 2012; Aron et al., 2004; Braver, 2012; Hernández et al., 2010; Ye & Zhou, 2009). However, there is still a piece of the puzzle missing: What drives executive control? What are the reasons behind the exertion of executive control? As Botvinick and Braver (2015) highlighted in their review, “control is motivated”. The decision to exert executive control is guided by different goals, which also influence the level of effort, persistence, and performance during executive control tasks.

As introduced before, goals impact engagement and performance during executive control tasks. However, the way in which a goal influences executive control may depend on its properties. One of such properties is goals’ hierarchical organization (e.g., for a review, see Austin & Vancouver, 1996; Carver & Scheier, 1982; Elliot & Church, 1997; Gollwitzer & Moskowitz, 1996). Goals are organized according to their level of abstraction, with specific, lower-level goals at the bottom, and more abstract, pocessing goals that are higher in the hierarchy (e.g., Grant & Gelety, 2009). Lower-level goals are usually framed in the general task instructions and indicate *what* needs to be done to complete the task. Without these lower-level goals, it is impossible to perform the task correctly, and therefore their active representation and maintenance is crucial. For example, task-switching paradigms require participants to perform one out of two discrete tasks on each experimental trial (e.g., to indicate whether a shape is a triangle or a circle; to indicate whether a shape is red or blue), and each of those tasks represents a lower-level goal. Processing goals, on the other hand, indicate *how* the task should be completed (e.g., responding fast or slow, processing the information deeply or shallowly, cooperating with others or competing, expressing or inhibiting specific beliefs). They are not directly linked to the general task instructions, but influence how individuals self-regulate their behaviour during the task.

In general, studies on executive control have considered lower-level goals typically as part of task instructions. Within this context, there is evidence on the impact of lower-level goals on task-switching (for reviews, see Kiesel et al., 2010; Monsell, 2003), the Stroop task (for a review, see MacLeod, 1991), or the Simon task (for a review, see Lu & Proctor, 1995). However, the effects of higher-level goals (e.g., processing goals) on performance have been rarely investigated. Notable exceptions can be found in the field of social and motivational psychology, with the main focus on the relation between epistemic motivation and executive control (e.g., Kossowska et al., 2014; Kruglanski & Kopetz, 2009). Need for closure (NFC), an epistemic motivation that focuses on knowledge formation processes, can be defined as a desire for a firm answer to a question, in opposition to ambiguity (Kruglanski & Webster, 1996). High levels of NFC – both as a state and as a trait – are related to lower interference and greater inhibition of irrelevant stimuli when performing executive control tasks (Kossowska, 2007a; Kossowska et al., 2014), although they are also linked to heuristic processing strategies (Bukowski et al., 2013), and even with difficulties in the processing of information when the cognitive load imposed by the task is high (Kossowska, 2007b; Kossowska et al., 2014; Roets et al., 2008). For example, Bukowski et al. (2013) found that individuals with higher levels of NFC, both dispositional and induced, were less accurate when reasoning about social relations because they relied more on information that was consistent with their background knowledge. In another study, Kossowska et al. (2014) discovered that induced high NFC (via two processing goals, to be fast or to be accurate) was linked to faster responses and smaller switch costs on a switching task, but also to lower accuracy when the task demands were higher. Nonetheless, attaining closure was not necessary to adequately pursue the lower-level goals of the task (i.e., to categorize faces according to their age or to their gender).

To sum up, besides the lower-level goals that are related to task instructions, both personal goals (e.g., to attain closure) and experimentally induced processing goals (e.g., to respond fast) play an important role in the processing strategies during an executive control task. They also seem critical in the ability to cope with events that require different degrees of flexibility. In general, research on executive control has taken into account the task goals that are triggered by general task instructions (i.e., lower-level goals), but less attention has been devoted to studying the influence of the change between processing goals on executive control.

Goal Maintenance and Goal Change

For goals to impact executive control efficiency, they must be activated and maintained over time; the mere presentation of a goal does not ensure its pursuit and attainment (Braver et al., 2002). The process of goal maintenance has been considered in the majority of executive control studies that analysed the impact of lower-level goals in response inhibition or information update (e.g., in the Stroop task, to name the colour and ignore the word; in the letter memory task, to remember the last letters of a list). In broad terms, when the lower-level goal is maintained, the task is performed correctly.

However, goals are not static and unchangeable over time. People disengage from some of their goals and re-engage in new ones, adapting their behaviour accordingly. The changing environments in which we live require constant adjustment, and individuals must be able to flexibly switch to a new goal when required (Altamirano et al., 2010). The concept of goal change includes two processes: goal disengagement, that is, the reduction of behavioural efforts and the decrease in psychological commitment toward a goal (Wrosch et al., 2013), and goal reengagement, understood as the identification, commitment, and pursuit of new goals (Wrosch, Scheier, Miller, et al., 2003). Although there are individual differences in goal disengagement capacity (e.g., Brandtstädter & Renner, 1990; Wrosch, 2011; Wrosch et al., 2007; Wrosch, Scheier, Miller, et al., 2003), the goal disengagement process tends to be more effective when an alternative goal is available (Wrosch, Scheier, Carver, et al., 2003), that is, when individuals activate and maintain a new goal. Goal disengagement and reengagement have been previously studied in relation to self-regulation processes and well-being, both in healthy (van Randenborgh et al., 2010; Wrosch, 2011; Wrosch et al., 2006; Wrosch, Scheier, Carver, et al., 2003; Wrosch, Scheier, Miller, et al., 2003) and in clinical populations (e.g., Neter et al., 2009; O'Connor et al., 2009; O'Connor et al., 2012).

One area in which goal disengagement and reengagement occur frequently is during multitasking. Multitasking has been defined as carrying out two or more tasks at the same time (Bühner et al., 2006). Nowadays, multitasking is part of our everyday lives in many environments, as school, work, or home (Bühner et al., 2006), especially with the development of modern technology platforms (e.g., Courage et al., 2015). From a goal perspective, multitasking requires constant goal change, since individuals must juggle between the goal representation of each task (e.g., Verbruggen et al., 2008), and these goal changes have consequences in everyday activities, even when the changes are voluntary (Junco & Cotten, 2012; Lau, 2017). Apart from its impact on daily activities, multitasking has been associated with a detriment in performance during tasks that require executive control (e.g., Adler & Benbunan-Fich, 2012; Arrington & Logan, 2004; Gollan & Ferreira, 2009), with the majority of evidence coming from task-switching studies (Kiesel et al., 2010; Monsell, 2003). Task-switching paradigms require participants to update constantly their mental representations to fulfil the task requirements, maintaining the task goals but also switching between them. Following the example from the previous section, the constant change between the two lower-level goals of categorizing figures by colour or shape has a negative impact on performance, with slower responses and more errors when it is necessary to switch between the two task goals compared to when the task is repeated (Kiesel et al., 2010; Monsell, 2003). Switching between the tasks can take place in a fixed sequence (e.g., Rogers & Monsell, 1995), or in a random sequence (e.g., Meiran, 1996). The interval between the response and the stimulus in the first case, and between the cue and the stimulus in the second case, can be manipulated, providing preparatory times that differ in their length. In general, larger preparatory times reduce the cost of switching (e.g., Hoffmann et al., 2003; Meiran, 1996; Nieuwenhuis & Monsell, 2002; Rogers & Mosell, 1995), especially under random switch conditions (Tornay & Milán, 2001). However, even with long preparatory times, this cost is not eliminated (Monsell, 2003). Although studies on task-switching provide a whole body of evidence on the impact of switching between task goals on executive control, the evidence is limited in the sense that they do not measure the impact of proactive change between processing goals (i.e., the voluntary change from the current processing goal to another processing goal), but focus instead on the impact of switching between lower-level goals (i.e., task goals).

What is the relation between goal maintenance and goal change? To explain the dynamic nature of persistence and flexibility that could be extrapolated to the concepts of goal maintenance and change, Hommel (2015) introduced the Metacontrol State Model. According to this model, persistence and flexibility act as two counteracting forces that must be balanced to ensure adaptive behaviour: Persistence facilitates focusing on relevant information but at the risk of ignoring other effective possibilities, whereas flexibility facilitates switching but at the risk of increased distraction and interference. The concepts of goal maintenance and goal change could be understood in a similar manner, that is, to ensure correct performance, we must be flexible and ready to change to a new goal without neglecting our current goal, finding the optimal balance between maintenance and change. Based on this idea, goal maintenance and goal change should not be considered as two separate processes, and their interaction must be evaluated when assessing the efficiency of executive control.

In conclusion, to understand the way in which goals influence executive control, it is worth examining jointly the goals' properties (i.e., their hierarchical organization) and the dynamics between the processes of goal maintenance and goal change. Therefore, we propose to investigate the influence of proactive change between processing goals on executive control, or, in other words, how the voluntary change from one processing goal to another (e.g., from a speed goal to an accuracy goal) impacts an important aspect of executive control, which is cognitive flexibility.

The Present Study

The aim of this study was to assess the impact of goal maintenance and goal change on the efficiency of executive control and, more specifically, task switching. For that reason, we modified a task-switching paradigm to include two processing goals, speed and accuracy, and we tested young adults, a group that is at the peak of their cognitive resources and exerts executive control at an optimal level (Karbach & Verhaeghen, 2014; Zelazo et al., 2004). So far, studies have analysed the impact of deficient goal maintenance in executive control tasks among healthy ageing (e.g., De Jong, 2001; Paxton et al., 2008) and clinical population, mostly suffering from dementia (e.g., Fernandez-Duque & Black, 2008; Rogers et al., 1998). However, older adults and individuals with some clinical pathologies have more difficulties to perform executive control tasks, and therefore the procedures used in these studies might not be sensitive enough to detect differences in individuals with high executive functions, for instance, healthy young adults. Moreover, the majority of these studies focus on specific task goals (i.e., lower-level goals, e.g., to indicate the direction of an arrow) and not on processing goals (i.e. higher-level goals, e.g., to respond quick or slow). As such, testing young adults serves not only the purpose of this study, but will also facilitate future research in other populations that differ in their levels of executive control, for example, bilinguals (e.g., Marzecová et al., 2013; Prior & MacWhinney, 2010; but see also Lehtonen et al., 2018), or musicians (e.g., Román-Caballero et al., 2020).

Although many tasks have been developed to measure the different components of executive control, we focused on the Social Category Switching Task (SCST, Marzecová et al., 2013), a task-switching paradigm that involves social stimuli and requires the categorization of faces according to their age (i.e., old vs. young) or their gender (i.e., male vs. female). The choice of the task was threefold. Firstly, we focus on category switching and flexibility as it seems that this aspect of executive control should be particularly prone to goal changes. Secondly, the processing of social information is strongly automatized, therefore switching between different social categories is more demanding in terms of cognitive flexibility than switching between non-social stimuli, as geometric shapes (Bukowski et al., 2019; Ito, 2011). Thirdly, the SCST has been used previously to measure the impact of induced goal-driven motivations (Kossowska et al., 2014) and turned out to be quite successful in this respect.

The SCST measures the flexibility of switching between two mental sets (i.e., switching between age and gender categorization rules). Switching from one categorization rule to the other requires higher levels of cognitive flexibility, which can be measured via switch costs, that is, the difference in reaction times between the trials in which switching between categorization rules is required, and the trials in which the same categorization rule is applied. Apart from the general levels of flexibility, the SCST measures also the flexibility required to manage the stimulus-set binding or, in other words, the association between a specific face and a categorization rule. The task-switching flexibility depends on the number of stimulus' features that are repeated from trial to trial, being harder to switch when the two features are repeated in two consecutive trials (e.g., two young women), compared to when they change partially (e.g., one young woman and one old woman), or completely (e.g., one young woman and one old man). In the study by Kossowska et al. (2014), that investigated the impact of induced goal-driven motivations on SCST performance, the authors found that participants who followed the speed goal had faster responses and smaller switch costs in reaction times. However, they also made more errors under the experimental conditions that involved a partial or complete change in the stimulus and therefore required higher levels of flexibility. On the other hand, the group of participants that followed the accuracy goal made fewer errors when the flexibility demands of the task were higher (i.e., partial repetition and complete alternation conditions), but at the cost of slower responses and larger switch costs. The results from this study show that the two goals led to the classical speed-accuracy trade-off, and that the influence of these two goals in performance was not restricted only to changes on average reaction times and accuracy, but also influenced other cognitive processes, as cognitive flexibility. Nonetheless, they measured only the impact of the maintenance of one processing goal, without including any goal change. In our study, we manipulated the same two goals, but adding the component of goal disengagement and reengagement.

In sum, our aim was to analyse the impact of goal maintenance and goal change on executive control and, more specifically, on cognitive flexibility, by adapting an existing task-switching procedure that would be sensitive enough to detect differences among young healthy adults. For that, we modified the SCST to include the manipulation of two processing goals: speed and accuracy. The obtained results should be useful not only for the understanding of executive control processes per se, but also other daily behaviours that are driven by goals, such as habit acquisition and change, or multitasking.

For the two experiments presented in this manuscript, we report how we determined our sample size, all data exclusions, all manipulations, and all measures (Simmons et al., 2012).

EXPERIMENT 1

In Experiment 1, participants completed a task-switching paradigm in which two processing goals were induced via instructions: to focus on speed or accuracy. The goals were presented sequentially to participants, that is, the change of the goal took place between each experimental block. We hypothesized a differential impact of each goal in performance, with shorter reaction times and smaller switch costs in reaction times when the speed goal was induced, but at the cost of lower accuracy (Kossowska et al., 2014), and higher levels of accuracy when the accuracy goal was induced, but at the cost of larger reaction times and switch costs in reaction times. In addition to our main hypothesis, we explored the influence of speed and accuracy goals on the ability to update the available information, that is, how these two goals might modulate the control of the interference driven by changes in the task and in the stimuli.

Method

Participants

Forty-seven adults participated in this study[1] (35 females, 12 males), with a mean age of 28 years (*SD* = 9.04). Participants were recruited through an online advertisement or via the university students' pool, and gave their informed consent to participate in the study. They received either money or course credits in exchange for their participation. This study complies with APA ethical standards and was approved by the ethical commission of Jagiellonian University.

Goal Manipulation

Participants completed a total of 6 experimental blocks of the SCST (Marzecová et al., 2013) following one of two goals: speed or accuracy. Goals were alternated between blocks, meaning that participants changed from one goal to the other after each block (see Figure 1). Before each new block, they received written instructions on the goal to follow. Specifically, before starting an accuracy block, participants were given the following instructions: *"In this part of the experiment, you will earn points by responding as correctly as you can, without making mistakes. It is very important to do this task the best you can, analysing all the information, even if it takes you more time. To obtain a good result, you must answer as correctly as possible, without making mistakes*". On the other hand, before each speed block, participants received these instructions: *"In this part of the experiment you will earn points by responding as fast as you can. It is very important to do this task as quickly as possible, without analysing the information deeply. To obtain a good result, you must answer as quickly as possible*". The goal order was counterbalanced between participants.

Stimuli and Procedure

The SCST is a cognitive task designed to test the ability to switch between two social categories (Marzecová et al., 2013). In this task, participants must categorize pictures of human faces according to their age (old vs. young) or their gender (male vs. female). Eight white-and-black photographs depicting a young male, an old male, a young female and an old female (two pictures per category) were selected from *The center for vital longevity database* (Minear & Park, 2004). All photographs had a width of 7.41 cm and a height of 6.74 cm and were displayed at the centre of the screen. On each trial, a visual cue (a green or purple coloured frame) informed participants of which task they should perform (age or gender categorization). Both tasks were presented on a random order to participants. The colour-task combination was counterbalanced, and the task was programmed using E-prime software (Schneider et al., 2002).

Each trial started with the presentation of a fixation cross for 1000 ms. Afterwards, the target picture was displayed in the middle of the screen, surrounded by either a purple or a green coloured frame. The cue and the target were presented simultaneously on each trial, that is, participants had no preparatory time between the cue and the target. Both remained on the screen until participants responded, or for a maximum duration of 3000 ms. The intertrial interval was 1500 ms, and participants received auditory feedback after errors (independently on the goal they followed). No feedback for correct responses was provided to avoid interference with the task switch manipulation and to not alter the original procedure beyond the goal manipulation. To respond, participants pressed the "z" and the "m" keys for the gender task, and the "x" and "n" keys for the age task. The matching of the keys to category exemplars was also counterbalanced across participants, and the stimuli were presented randomly to each participant.

First, participants completed a practice block of eight trials, followed by 6 experimental blocks of 80 trials each. In half of the blocks, participants were instructed to follow the accuracy goal, whereas in the other half they were instructed to follow the speed goal (see Figure 1). Before each experimental block, they received specific written instructions on the goal to follow.

Design and Data Analysis

Two within-subjects variables were considered for the confirmatory analysis: goal and task switch. The goal variable (speed vs. accuracy) was related to the particular goal participants were required to follow, and the task switch variable (switch vs. no switch) referred to whether participants had to switch between tasks on two consecutive trials (e.g., to categorize by age in the first trial and by gender in the second), or whether the task remained identical.

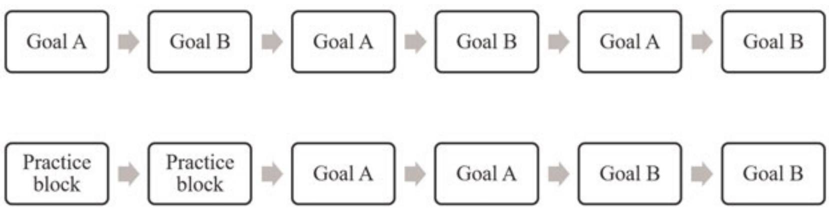

Figure 1. Experimental design of Experiment 1 (Top) and Experiment 2 (Bottom)

Note. In Experiment 1, participants completed 6 experimental blocks changing from one goal to another after each block. They received auditory feedback after errors in all blocks. In Experiment 2, participants completed two practice blocks with no goal manipulation, followed by two blocks dedicated to each goal. They received auditory feedback after errors during the practice blocks, and written feedback after each block during the experimental blocks. The written feedback indicated either the average reaction time (for speed blocks) or the average accuracy rate (for accuracy blocks). The goal order was counterbalanced across participants in both experiments.

Apart from the confirmatory analysis, we conducted an exploratory analysis to investigate the influence of goals in the processing of task-driven and stimulus-driven interference. In other words, we explored whether participants' ability to update the stimulus-set binding (i.e., the association between a specific stimulus and a task) was different when following the speed versus the accuracy goal. For this analysis, two other variables were considered: task and type of repetition. The task variable (age vs. gender) referred to under which category participants had to categorize the faces, and the type of repetition variable (complete repetition vs. partial repetition vs. complete alternation) referred to the number of features that were repeated in two consecutive trials: under the complete repetition condition, the two pictures shared the same features (e.g., a "young female" was followed by another "young female"); under the partial repetition condition, only one feature was repeated (e.g., a "young woman" was followed by an "old woman"), and under the complete alternation condition, the opposite features were presented (e.g., a "young woman" was followed by an "old man"). The task switch and the type of repetition variables were coded offline. All analyses were implemented in R using the stats package (version 4.0.0, R Core Team, 2020), pairwise comparisons were computed with the package emmeans (version 1.5.2-1, Lenth, 2020), and partial Eta-squared was calculated with the DescTools package (version 0.99.36, Signorell et al., 2016). Plots were created with the package ggplot2 (version 3.3.2, Wickham, 2016).

Results

Reaction Times

Two participants were excluded due to a lower accuracy rate (< 30%). Therefore, analyses were conducted with data from 45 participants. Erroneous responses and reaction times (RTs) shorter than 200 ms and longer than 2000 ms[2], as well as the first trial of each block[3], were excluded from the analysis (altogether 14.26%). The 8 practice trials were also removed. On average and per participant, 412 trials from the total 480 trials remained after filtering (SD = 48.21; range = 264 – 465)[4]. The proportion of valid trials for the conditions goal and task switch can be consulted in the Appendix, Table A, and the distribution of reaction times after filtering is depicted in Figure 2.

To test our main hypothesis, we conducted a repeated measures ANOVA with two within-subject factors: goal (speed vs. accuracy) and task switch (switch vs. no switch). The analysis revealed a main effect of goal, $F(1, 44) = 53.75$, $p < .001$, $\eta_p^2 = .55$, and a main effect of task switch, $F(1, 44) = 122.22$, $p < .001$, $\eta_p^2 = .74$, but no significant interaction, $F(1, 44) = 0.19$, $p = .66$, $\eta_p^2 = .00$. As expected, participants responded faster during the speed blocks compared to the accuracy blocks (M = 955 ms vs. M = 1076 ms; see Figure 3), and in non-switch trials than in switch trials (M = 952 ms vs. M = 1079 ms), but there were no differences in switch costs between the goals (M_{speed} = 129 ms vs. $M_{accuracy}$ = 125 ms).

To test the impact of goals on the control of task-driven and stimulus-driven interference, we ran another ANOVA including the task (age vs. gender) and the type of repetition (complete repetition vs. partial repetition vs. complete alternation) as within-subject factors. Apart from the main effect of goal, $F(1, 44) = 52.08$, $p < .001$, $\eta_p^2 = .54$, none of the effects of interest involving goal reached significance. However, the absence of interactions in this exploratory analysis needs to be considered with caution due to the sample size. The observed means in all conditions can be consulted in Table 1, and the complete exploratory analysis is summarized in the Appendix, Table B.

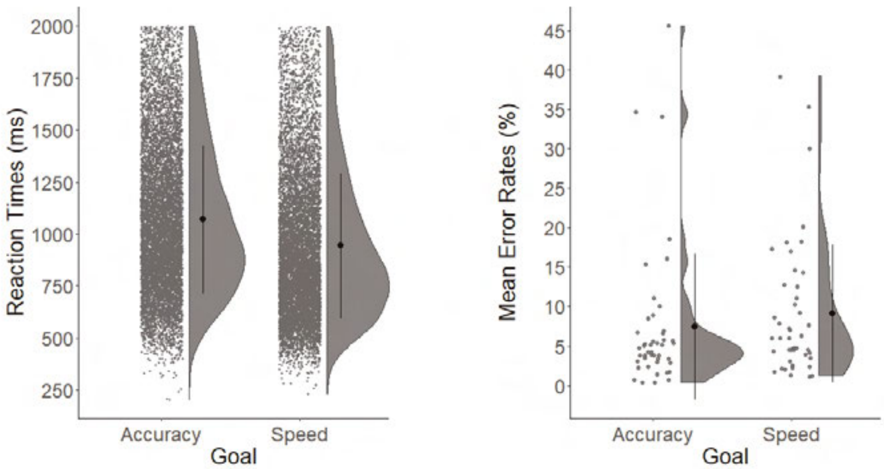

Figure 2. Distribution of Filtered Reaction Times (Left) and Average Error Rates (Right) per Participant as a Function of the Goals in Experiment 1

Note. The figures represent raincloud plots (Allen et al., 2019) of reaction times (RTs) and error rates as a function of the goals (accuracy, speed). For each goal, the raincloud plot combines jittered points (i.e., randomly separated points, left) with a half violin plot (right). The half violin plot represents the probability density function (i.e., the probability of a given value within the population), and the jittered points are, in this case, either individual filtered RTs, or average error rates per participant and goal. Lines represent one standard deviation above and below the mean. Filtered RTs included correct responses that were longer than 200 ms and shorter than 2000 ms. The first trial of each block was also removed for RTs and error rates.

Table 1 Observed Means (and Standard Deviations) for Reaction Times and Error Rates for all Experimental Conditions in Experiment 1 and Experiment 2

				Experiment 1		Experiment 2	
Goal	**Task**	**Repetition type**	**Task switch**	**Reaction time (ms)**	**Error rate (%)**	**Reaction time (ms)**	**Error rate (%)**
Accuracy	Age	Complete alternation	No switch	1092 (352)	7.31 (26.05)	978 (327)	3.41 (18.16)
			Switch	1166 (369)	10.80 (31.06)	1040 (321)	3.46 (18.29)
		Complete repetition	No switch	896 (332)	3.13 (17.41)	825 (282)	0.77 (8.77)
			Switch	1170 (343)	10.36 (30.49)	1038 (321)	5.91 (23.61)
		Partial repetition	No switch	1026 (352)	8.79 (28.33)	954 (324)	2.68 (16.15)
			Switch	1165 (358)	8.96 (28.57)	1025 (330)	3.25 (17.75)
	Gender	Complete alternation	No switch	1064 (323)	8.39 (27.74)	975 (313)	2.88 (16.75)
			Switch	1073 (348)	8.02 (27.17)	1033 (329)	1.77 (13.20)
		Complete repetition	No switch	879 (307)	2.59 (15.90)	828 (305)	0.77 (8.77)
			Switch	1087 (337)	5.09 (22.00)	971 (323)	2.72 (16.29)
		Partial repetition	No switch	1045 (345)	6.66 (24.94)	945 (322)	1.41 (11.79)
			Switch	1108 (350)	6.56 (24.76)	1021 (328)	2.69 (16.18)
Speed	Age	Complete alternation	No switch	950 (350)	7.48 (26.32)	852 (335)	9.84 (29.82)
			Switch	1023 (360)	11.88 (32.38)	922 (331)	12.53 (33.14)
		Complete repetition	No switch	768 (289)	2.53 (15.72)	708 (266)	2.62 (15.99)
			Switch	1024 (367)	12.15 (32.69)	907 (331)	11.34 (31.75)
		Partial repetition	No switch	910 (330)	11.47 (31.87)	829 (308)	9.60 (29.48)
			Switch	1035 (371)	11.33 (31.70)	899 (326)	10.66 (30.87)
	Gender	Complete alternation	No switch	954 (310)	8.58 (28.03)	870 (308)	4.78 (21.37)
			Switch	994 (357)	7.63 (26.56)	862 (320)	6.80 (25.21)
		Complete repetition	No switch	772 (308)	3.22 (17.67)	712 (300)	4.11 (19.88)
			Switch	969 (327)	10.17 (30.25)	855 (322)	8.02 (27.19)
		Partial repetition	No switch	911 (337)	9.08 (28.74)	797 (310)	6.83 (25.23)
			Switch	971 (343)	8.81 (28.36)	891 (337)	7.73 (26.71)

Error Rates

The mean error rate was 8.40%. The first trial of each block was removed and, as for the RTs, we conducted a repeated measures ANOVA with two within-subject factors: goal and task switch (see Figure 2 for the distribution of the average error rates per participant and goal). The analysis revealed a main effect of goal, $F(1, 44) = 5.45$, $p = .024$, $\eta_p^2 = .11$, with more errors when the speed goal was salient ($M = 9.13\%$ vs. $M = 7.41\%$; see Figure 3), and a main effect of task switch, $F(1, 44) = 11.28$, $p = .002$, $\eta_p^2 = .20$, with more errors in switching trials versus non-switching trials ($M = 9.33\%$ vs. $M = 7.21\%$).The interaction between goal and task switch was not significant, $F(1, 44) = 1.56$, $p = .22$, $\eta_p^2 = .03$, with no differences in switch costs when following the speed or the accuracy goal ($M_{speed} = 2.58\%$ vs. $M_{accuracy} = 1.66\%$).

Again, we conducted a subsequent analysis to explore the impact of goals on the processing of task-driven and stimulus-driven interference. For that, we ran an ANOVA including the task and the type of repetition as within-subject factors. As in the confirmatory analysis, the main effect of goal was significant, $F(1, 44) = 5.22$, $p = .027$, $\eta_p^2 = .11$. The three-way interaction between goal, task switch and repetition type was also significant, $F(2, 88) = 3.38$, $p = .038$, $\eta_p^2 = .07$, and therefore we calculated the switch costs for each type of repetition and goal. Pairwise comparisons revealed that participants had larger switch costs when following the speed goal than when following the accuracy goal, but only when the features of the stimulus were repeated in two consecutive trials, $t(132) = -3.054$, $p = .003$ (M_{speed}= 8.49% vs. $M_{accuracy}$ = 4.77%). As with the reaction time exploratory analysis, the results from this analysis should be interpreted with caution, due to the sample size. The observed means in all conditions can be consulted in Table 1, and the complete exploratory analysis is summarized in the Appendix, Table B.

Discussion

Within this experiment, we explored the impact of goal changes on performance during a task-switching paradigm. For that, we asked participants to complete the SCST while following a specific processing goal (to focus on speed or accuracy). Goals were manipulated within-subjects, and participants had to change goals after each experimental block. For the speed goal, we predicted faster responses and smaller switch costs in reaction times but at the cost of reduced accuracy, whereas for the accuracy goal, the opposite pattern was expected, that is, fewer errors but larger RTs and switch costs.

The results partially support our hypothesis: Participants responded faster but also made more errors when the speed goal was salient compared to when the accuracy goal was salient. This suggests that following a speed or an accuracy goal has a differential impact in the response strategy, with the focus put either on faster responses at the cost of accuracy, or vice versa. However, based on the study by Kossowska et al. (2014), we also predicted reduced switch costs in reaction times when following the speed goal. Contrary to this prediction, the switch costs were the same for both goals. The differences in the results between the two studies might have been caused by the differences in how goals were manipulated across studies. In the study by Kossowska et al., goals were manipulated between-subjects, meaning that participants did not change between the accuracy and the speed goal, but followed only one of the two goals throughout the entire experiment. Apart from this difference, we also identified some methodological limitations in our procedure that might have influenced our results. These limitations are discussed in detail below.

In addition to our primary results, exploratory analyses showed that the cost in accuracy associated with the speed goal was larger under the complete repetition condition when the task switched. The results suggest that induced speed is associated with more difficulties to update the stimulus-set binding under task conditions that require higher levels of flexibility, that is, when the task changes but the stimulus remains the same. This goes in line with a previous finding of Kossowska et al. (2014), which showed lower accuracy in the SCST under the speed goal, but only when it was necessary to update the available information, or more specifically, when there was a change in the stimulus from trial to trial. Nonetheless, this last finding should be interpreted with caution, since the sample size of our experiment was small for the complexity of the exploratory analysis. In summary, the results from this experiment indicate that performance in a task-switching paradigm is impacted by the current

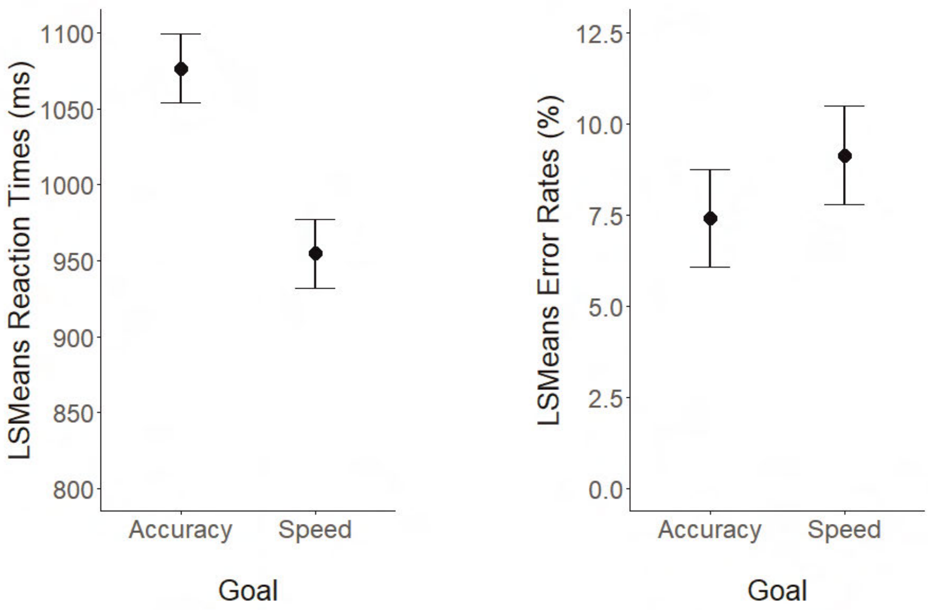

Figure 3. Least-squares Means of Reaction Times and Error Rates as a Function of the Goals in Experiment 1. Error Bars Represent Standard Errors

Note. Results are averaged on the level of task switch. LSMeans = Least-squares means.

goals, at least when those goals are framed in terms of speed and accuracy. However, previous evidence has found differences in switch costs as a function of the active goal (Kossowska et al., 2014), and we did not find such differences.

As mentioned before, this experiment exposed some limitations of the procedure employed. First, the duration of the practice might not have been sufficient to ensure task automatization before engaging on each goal efficiently. The SCST is a complex task that requires learning several rules and associations, and in our experiment, participants completed only 8 practice trials before starting the experimental blocks with the goal manipulation. Second, the constant goal change might have imposed extra demands in the maintenance of a correct goal representation. The change between goals occurred after each experimental block, or, in other words, every 80 trials, and participants might not have had enough time to represent each goal and maintain an active representation of it. Third, the type of feedback that participants received might have had detrimental effects in the processes of goal engagement and active goal maintenance for the speed goal. Participants received auditory feedback after errors, but no information regarding the quickness of their responses. Auditory feedback facilitates the learning of the task, but also makes salient the importance of accurate responses during the speed blocks. We addressed these three identified limitations in the second experiment.

EXPERIMENT 2

This second experiment aimed at addressing the limitations found in the first experiment and therefore improve the experimental procedure used to evaluate the impact of goal maintenance and change on executive control. First, to ensure that participants were familiar with the task and could actively pursue each goal, we extended the practice session. Second, to facilitate the maintenance of each goal and guarantee that each goal was followed for a sufficient period of time, we introduced only one change of goals through the task. This way, participants completed two consecutive blocks following one goal, and two consecutive blocks following the other goal. Third, to help participants in the process of task automatization and make both goals equally salient, the feedback that participants received was modified: During the practice session, as in the procedure tested in the first experiment, participants received auditory feedback for errors; however, this time, during the experimental blocks, instead of auditory feedback, they received written information on their average reaction time (for the speed goal) or on their average accuracy (for the accuracy goal) at the end of each block.

The hypothesis of this second experiment was the same as the one stated for the first experiment, that is, that the induction of speed and accuracy goals influences performance during the SCST. Specifically, when the speed goal was salient, we predicted a reduction in reaction times and in switch costs for reaction times, but at the cost of reduced accuracy. When the accuracy goal was salient, we predicted the opposite pattern: an increase in accuracy at the cost of larger reaction times and larger switch costs for reaction times.

Method

Participants

We recruited 47 participants (32 females, 15 males), with a mean age of 23 years (*SD* = 5.31). The recruitment process took part through an online advertisement and via the university students' pool. Participants gave their informed consent to participate in the study and received either money or course credits in exchange for their participation. This study complies with APA ethical standards and was approved by the ethical commission of Jagiellonian University.

Goal Manipulation

Participants completed a total of 4 experimental blocks following the same processing goals as in Experiment 1, speed and accuracy. In this second experiment, each goal was active for two consecutive blocks, and therefore the goal change occurred only once, between the second and the third experimental block (see Figure 1). We used the same instructions as in Experiment 1, which were presented to participants before each experimental block (including before the blocks without goal change). Goal order was counterbalanced between participants.

Stimuli and Procedure

The stimuli and general procedure were identical to Experiment 1. However, goals were manipulated differently. Participants completed a total of 6 blocks but, to ensure task automatization, the first two blocks were considered as practice. During these two blocks, participants heard a sound after incorrect responses and no goal was specified. Goals were manipulated in the remaining 4 blocks, with two consecutive blocks dedicated to one goal (either speed or accuracy), and the remaining two blocks to the opposite goal (see Figure 1). During these experimental blocks, instead of auditory feedback, participants received written information on their performance at the end of each block. The feedback provided in the 4 experimental blocks was related to the goal that participants were following, that is, they received feedback on their average accuracy rate (accuracy blocks) or their average response time (speed blocks).

Design and Data Analysis

The design and analyses were identical to Experiment 1. First, to test our main hypothesis, we ran an ANOVA with two within-subjects variables: goal (speed vs. accuracy) and task switch (switch vs. no switch). Then, we conducted a second ANOVA to explore the influence of goals in task-driven and stimulus-driven interference processing. For that, we included the task (age vs. gender) and the type of repetition (complete repetition vs. partial repetition vs. complete alternation) as within-subject variables. Again, the task switch and the type of repetition variables were coded offline.

Results

Reaction Times

One participant was excluded from the analysis due to a lower accuracy rate (M = 52%), and two participants were excluded due to missing data in some conditions. Therefore, the analyses were conducted with data from 44 participants[5]. Only RTs from the experimental blocks (i.e., four blocks that included the goal manipulation) were considered for the analyses. Erroneous responses and RTs shorter than 200 ms and longer than 2000 ms, as well as the first trial of each block, were also excluded (altogether 9.86%)[6]. On average, 288 trials from the total 360 trials per participant remained after filtering (SD = 23.56; range = 207 – 313)[7]. The proportion of valid trials considering the conditions of goal and task switch can be consulted in the Appendix (Table A), and the distribution of reaction times after filtering is depicted in Figure 4.

To test our main hypothesis, we conducted a repeated measures ANOVA with two within-subject factors: goal (speed vs. accuracy) and task switch (switch vs. no switch). The main effect of goal was significant, $F(1, 43) = 35.78$, $p < .001$, $\eta_p^2 = .45$, as well as the main effect of task switch, $F(1, 43) = 126$, $p < .001$, $\eta_p^2 = .75$, but not the interaction between goal and task switch, $F(1, 43) = 0.76$, $p = .39$, $\eta_p^2 = .02$. Participants reacted faster when following the speed goal (M = 845 ms vs. M = 985 ms; see Figure 5), and under the non-switch condition (M = 867 ms vs. M = 963 ms). However, and contrary to our expectations, there were no differences in switch costs between the goals (M_{speed} = 90 ms vs. $M_{accuracy}$ = 101 ms).

As in Experiment 1, we explored the impact of goals on the processing of task-driven and stimulus-driven interference. For that, we conducted a second ANOVA including the task (age vs. gender) and the type of repetition (complete repetition vs. partial repetition vs. complete alternation) as within-subject factors. Apart from the main effect of goal, $F(1, 43) = 35.49$, $p < .001$, $\eta_p^2 = .45$, none of the effects of interest involving goal reached significance. It is important to note that the absence of interactions in the exploratory analysis needs to be considered with caution due to the sample size (see Table 1 for the observed means in all conditions and the Appendix, Table B, for the complete exploratory analysis).

Error Rates

The mean error rate was 5.46%. First, we conducted a repeated measures ANOVA with two within-subject factors, goal and task switch (see Figure 4 for the distribution of the average error rates per participant and goal). The main effect of goal was significant, $F(1, 43) = 18.90$, $p < .001$, $\eta_p^2 = .31$, with higher error rates when the speed goal was salient (M = 8.16% vs. M = 2.60%; see Figure 5), as well as the main effect of task switch, $F(1, 43) = 18.64$, $p < .001$, $\eta_p^2 = .30$, with more errors in switching trials than in non-switching trials (M = 6.24% vs. M = 4.52%). The interaction Goal x Task switch was not significant, $F(1, 43) = 2.24$, $p = .14$, $\eta_p^2 = .05$.

Again, we explored the impact of goals on task-driven and stimulus-driven interference processing. For that, we conducted a second ANOVA including task and repetition type as within-subject factors. As in the confirmatory analysis, the main effect of goal was significant, $F(1, 43) = 20.15$, $p < .001$, $\eta_p^2 = .32$. Moreover, the interaction between goal and task switch was also significant, $F(1, 43) = 7.54$, $p = .009$, $\eta_p^2 = .15$, with larger switch costs when following the speed goal compared to the accuracy goal (M = 3.32% vs. M = 1.04%). Lastly, there was a significant three-way interaction between goal, task and repetition type, $F(2, 86) = 4.05$, $p = .021$, $\eta_p^2 = .09$. When following the speed goal, participants had more difficulties to perform the age categorization task under the complete

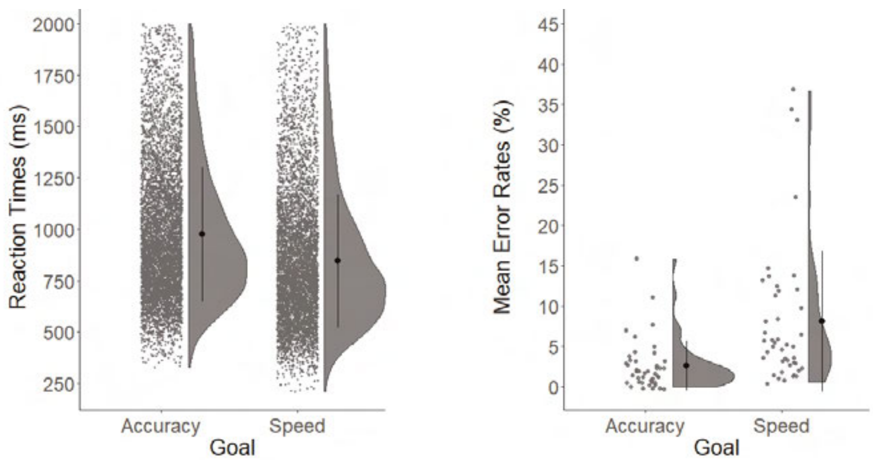

Figure 4. Distribution of Filtered Reaction Times (Left) and Average Error Rates (Right) as a Function of the Goals in Experiment 2

Note. Raincloud plots (Allen et al., 2019) of reaction times (RTs) and error rates as a function of the goals (accuracy, speed). The half violin plot represents the probability density function, and the jittered points are, in this case, either individual filtered RTs, or average error rates per participant and goal. Lines represent one standard deviation above and below the mean. Filtered RTs included correct responses that were longer than 200 ms and shorter than 2000 ms. The first trial of each block was also removed for RTs and error rates.

alternation condition (M_{age} = 11.6% vs. M_{gender} = 5.34%), $t(215) = 5.02$, $p < .001$, and under the partial repetition condition (M_{age} = 10.38% vs. M_{gender} = 7.41%), $t(215) = 2.39$, $p = .018$. However, when following the accuracy goal, there were no differences between the tasks for any of the three types of repetition (all *ps* > .05). Again, we address the importance of considering the sample size when interpreting the results from this exploratory analysis. The observed means for all conditions are summarized in Table 1, and the complete results from the exploratory analysis can be consulted in the Appendix, Table B.

Discussion

The objective of the second experiment was to improve the experimental procedure used to measure the impact of processing goals on executive control. The results from the second experiment partially support our initial hypothesis: As in Experiment 1, participants adjusted their behaviour according to their current goals, with faster responses but lower accuracy when following the speed goal, and higher accuracy but slower responses when following the accuracy goal. Moreover, when the task and the type of repetition were controlled for in the exploratory analysis, participants showed smaller switch costs in accuracy when following the accuracy goal. However, we did not find the expected differences in switch costs for the reaction times neither in the confirmatory nor in the exploratory analysis.

The results from this second study showed that goals also impacted the ability to update the stimulus-set binding, that is, the association between a specific stimulus and a categorization rule. The cost in accuracy associated with faster responses was more prominent when the task demands were higher, that is, when the stimuli changed completely or partially from trial to trial during the age categorization task. Age categorization requires a distinction between less well-determined classes (Mouchetant-Rostaing & Giard, 2003), and the change of stimulus (both complete and partial change) requires higher levels of cognitive flexibility. As with Experiment 1, we highlight the importance of interpreting carefully this last interaction from the exploratory analysis, due to the sample size of our study.

COMPARISON BETWEEN EXPERIMENT 1 AND EXPERIMENT 2

Our goal was to study the impact of goal maintenance and goal change on the efficiency of executive control. For that, we modified and tested an existing task-switching paradigm, the SCST (Marzecová et al., 2013), across two experiments. In order to evaluate how goals influence executive control, the experimental procedure must meet two assumptions: First, the time dedicated to the pursuit of each goal before changing to a new goal has to be sufficient in order to observe changes in performance that are driven by the goal. Second, to measure the effects of goal change, the procedure must ensure the correct engagement on each goal; if there is no goal engagement, there will be no impact of changing goals because disengagement from any previous goal is not necessary.

The two procedures employed in this study differed in the required duration of the goal maintenance and in the frequency with which the goals changed. The procedure tested in Experiment 1 included relatively frequent goal changes (hence, the maintenance of a given goal was relatively short), whereas the procedure tested in Experi-

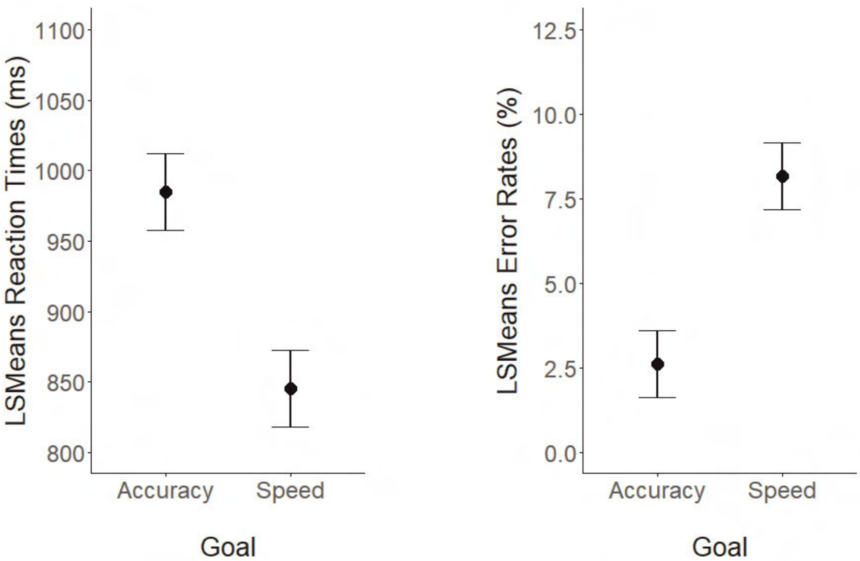

Figure 5. Least-squares Means of Reaction Times and Error Rates as a Function of the Goals in Experiment 2. Error Bars Represent Standard Errors

Note. Results are averaged on the level of task switch. LSMeans = Least-squares means.

ment 2 included less frequent goal changes (hence, the expected goal maintenance was longer). Below, we report the results of the omnibus analysis that included experiment as a factor.

Results

Reaction Times

We ran an ANOVA with two within-subject variables, goal (speed vs. accuracy) and task switch (switch vs. no switch), and one between-subject variable, experiment (Experiment 1 vs. Experiment 2). The main effect of goal and the main effect of task switch were significant, $F_1(1, 87) = 83.79, p < .001, \eta_p^2 = .49, F_2(1, 87) = 241.58, p < .001, \eta_p^2 = .74$, as well as the main effect of experiment, $F(1, 87) = 9.60, p = .003, \eta_p^2 = .10$, and the interaction between experiment and task switch, $F(1, 87) = 4.68, p = .033, \eta_p^2 = .05$. Those participants that completed the procedure changing goals frequently (Experiment 1) had, on average, larger response times (M = 1016 ms vs. M = 915 ms), as well as larger switch costs (M = 126 ms vs. M = 95 ms), compared to those participants who faced only one goal change during the experiment (Experiment 2). The complete analysis is summarized in Table 2.

Error Rates

The same analysis was conducted for error rates. The main effect of goal and the main effect of task switch were significant, $F_1(1, 87) = 24.31, p < .001, \eta_p^2 = .22, F_2(1, 87) = 26.28, p < .001, \eta_p^2 = .23$, as well as the interaction between experiment and goal, $F(1, 87) = 6.84, p = .010, \eta_p^2 = .07$. Although participants in both experiments made fewer errors when following the accuracy goal than the speed goal, as shown in the analyses of each experiment, the effect was larger in Experiment 2. Looking at the interaction from another perspective, when participants followed the accuracy goal, they were less accurate when they had to change frequently between goals (Experiment 1) than when they only changed goals once (Experiment 2), $t(126) = 2.87, p = .005$. However, there were no significant differences between experiments when following the speed goal, $t(126) = 0.58, p = .56$. The complete analysis is summarized in Table 2.

Discussion

These results show that frequent goal changes in Experiment 1 had more detrimental effects on performance, compared to the only one goal change in Experiment 2. Worse performance in Experiment 1 was observed in overall reaction times and in switch costs in reaction times. Moreover, frequent goal changes were also associated with smaller differences in accuracy between the goals, with lower accuracy when following the accuracy goal in Experiment 1 compared to Experiment 2.

In general, it seems that frequent goal changes have a more negative impact on performance, and also impair the ability to follow an accuracy goal. The results from these analyses go in line with literature on multitasking showing larger performance difficulties when frequent goal changes take part, compared to when goals are followed sequentially (Adler & Benbunan-Fich, 2012). However, there is a difference between our two procedures that needs to be considered when interpreting the reaction time results: the larger practice session of Experiment 2. Practice is associated with a reduction in reaction times and in switch costs (e.g., Karbach & Kray, 2009; Zinke et al., 2012), and could explain the differences in reaction times and switch costs between both experiments. This hypothesis could be tested in the future by increasing the practice session in the procedure used in Experiment 1 and comparing the results with those from Experiment 2.

Overall, the second procedure might be more appropriate to measure the influence of goal maintenance and goal change on the efficiency of executive control, since it made possible the following of each goal without eliminating the goal changes. This does not mean that the procedure presented in the first experiment is not valid for other purposes, for example, to evaluate how individuals from groups associated with higher or lower efficiency in their executive control respond to frequent goal change

Table 2. *Summary of Omnibus Analyses Combining Experiment 1 and Experiment 2*

	df	ANOVA reaction times		ANOVA error rates	
		F	η_p^2	*F*	η_p^2
Experiment	1, 87	9.60**	.10	3.67	.04
Goal	1, 87	83.79***	.49	24.31***	.22
Task Switch	1, 87	241.58***	.74	26.28***	.23
Experiment x Goal	1, 87	0.38	.00	6.84*	.07
Experiment x Task Switch	1, 87	4.68*	.05	0.28	.00
Goal x Task Switch	1, 87	0.14	.00	3.79	.04
Experiment x Goal x Task Switch	1, 87	0.91	.01	0.09	.00

Note. *$p > .05$; ** $p > .01$; ***$p < .001$

(e.g., bilinguals vs. monolinguals). Nonetheless, before using the procedure presented in Experiment 1, we would recommend its modification to include the extended practice and the changes in the feedback that were implemented in Experiment 2.

GENERAL DISCUSSION

In the last decades, research on motivation and goals has flourished, with a considerable number of studies exploring the impact of goals on human development and well-being, as well as its influence in different cognitive processes, including executive control. There is an agreement among the scientific community on the importance of executive control in the regulation of several other cognitive processes. However, the majority of studies in executive control have not taken into consideration the important role of goal maintenance and goal change in both the engagement in executive control and in performance during executive control tasks. The current paper reports two experiments that aimed at measuring the interaction between goals and executive control. For that, we modified the SCST (Marzecová et al., 2013) by manipulating two goals, speed and accuracy.

Our results show that, when the active goal requires quick responses, there is a reduction in reaction times but an increase in the number of errors. On the other hand, when the active goal requires accurate responses, the accuracy increases, but response times get longer. Moreover, in our second experiment, we found reduced switch costs in accuracy when following the accuracy goal, but only when controlling for task and type of repetition (i.e., in the exploratory analysis). Taken together, the results reveal that proactive engagement in processing goals influences human behaviour during the exertion of executive control.

Apart from our main results, the exploratory analyses also suggested that following a speed goal was associated with more difficulties to update the stimulus-set binding (i.e., the association between a specific stimulus and a categorization rule), under specific experimental conditions that required higher levels of cognitive flexibility. When the speed goal was salient in Experiment 1, we observed a decrease in accuracy when switching between tasks was required but the stimulus' features remained identical (complete repetition condition). When the speed goal was salient in Experiment 2, the accuracy was lower when one specific aspect of the stimulus needed to be ignored (partial repetition condition), or when it was necessary to re-establish the stimulus-task binding (complete alternation condition). The results suggest that goals impact not only general performance, but also the ability to update the available information related to the task and to the stimulus. Further studies are needed to clarify exactly under which conditions speed and accuracy goals impair or facilitate the processing of information that demands higher cognitive flexibility.

Nonetheless, our hypothesis was not fully confirmed by the data. We did not find differences in switch costs for reaction times between the two goals in either of the two experiments. Previous literature has reported advantages in cognitive flexibility (i.e., reduced switch costs in reaction times) when speed goals are induced (Kossowska et al., 2014), but such an advantage was not detected in our experiments. The main reason for this discrepancy could be the methodological differences between our study and the study by Kossowska et al. (2014). In the experiment conducted by Kossowska and colleagues, the processing goals were manipulated between subjects, meaning that participants did not change goals at any moment. Empirical evidence on multitasking and task switching has shown that goal change has a cost (e.g., Adler & Benbunan-Fich, 2012; Arrington & Logan, 2004; Gollan & Ferreira, 2009; Kiesel et al., 2010). The SCST is a difficult task in itself, and the inclusion of changes between processing goals probably incremented its complexity. In fact, some studies have found a curvilinear relation between task demands and performance, with decreased efficiency under increased task demands (Kossowska, 2007b; Zivnuska et al., 2002). The difficulty of the SCST, together with the extra cost imposed by the goal changes, might have reduced the advantages in cognitive flexibility that are associated with speed goals.

In conclusion, the results from both experiments illustrate the importance of processing goals on the efficiency of executive control. Although there were some differences between both experiments, probably as a result of how the goal changes were manipulated, the results go in the same line: following a speed goal (vs. an accuracy goal) increases the quickness of response, but impairs the accuracy and reduces the ability to update the stimulus-set binding, especially when the task demands are high. This suggests that goals affect the efficiency of executive control, at least when this efficiency is assessed through reaction times, error rates and switch costs in error rates.

Comparison Between Procedures

In this study, we aimed at measuring the impact of both goal maintenance and goal change on the efficiency of executive control and, more specifically, on task switching. The experimental procedure selected to fulfil this objective must allow the active engagement in each goal for a sufficient period of time to (1) observe its influence on participants' behaviour and (2) measure the possible consequences of goal change. There are a few differences between the experimental procedures tested in this study that might play a role in the way in which goals affected performance. The most important difference is the number of goal changes. More frequent goal change implies shorter exposure to each goal, which might have negative consequences for the process of goal engagement. In the first experiment, participants changed goals after each experimental block, with a total of five changes, whereas in the second experiment the goal change occurred only once.

When comparing the performance in both procedures, we observed that the frequent goal change (Experiment 1) was accompanied by longer reaction times and also larger switch costs compared to a single goal change (Experiment 2), suggesting that frequent goal changes hinder both general performance and cognitive flexibility. Nevertheless, as mentioned before, an alternative explanation could be considered: the extended practice of Experiment 2 might be driving the differences between experiments in reaction times and switch costs for reaction times. Future studies including extended practice together with frequent goal changes will help to extract a clearer conclusion on the impact of multiple versus single goal changes in reaction times' performance. Regarding the error rates analysis, frequent goal changes made the active maintenance of the accuracy goal harder, with higher error rates when following the accuracy goal in the first procedure compared to the second. Altogether, the comparison between the two procedures suggests that changing from one goal to another does not necessarily lead to deterioration of performance, but a larger number of changes might increase the task demands and complicate the process of goal maintenance.

As discussed previously, our second procedure might be more adequate to measure how goal maintenance and goal change influence the efficiency of executive control. The results of the comparison between both procedures indicate a stronger goal engagement in Experiment 2, which in consequence allows the introduction of a meaningful goal change. In addition, the second procedure addressed some limitations that were detected after testing the first procedure, increasing the practice and modifying the feedback that participants received.

Contributions of this Study and Future Directions

To our knowledge, this is the first study that measures the impact of goal maintenance together with goal change on executive control. In both experiments, we found differences in performance driven by the experimental manipulation of the goals, despite testing young adults, a group that is on their peak capacities in terms of executive control and is less vulnerable to experimental manipulations during executive control tasks. The fact that our manipulations were successful among this population indicates that the task can be used in other groups with larger variability in their executive control, as bilinguals, musicians, or video game players. Task-switching studies have found that individuals from these particular groups might have a greater ability to follow the task goals and to switch between them (for bilinguals and musicians see e. g., Marzecová et al., 2013; Moradzadeh et al., 2015; Prior & MacWhinney, 2010; for video game players see e.g., Shawn Green et al., 2012; Strobach et al., 2012). Following this idea, bilinguals, musicians, or video game players might also engage more effectively on processing goals, showing larger behavioural differences depending on the goal they follow (e.g., a larger reduction in reaction times when following speed vs. accuracy goals). They might be also more resistant to the impact of goal changes, being able to change goals more efficiently, even when this change occurs with relative high frequency. Both procedures could be used to test these hypotheses, that is, the ability of these individuals to maintain and change goals effectively (procedure from Experiment 2), as well as their ability to adjust to frequent goal changes (procedure from Experiment 1 after implementing changes on the practice length and the type of feedback).

Limitations

There are some limitations of this research that must be taken into consideration. First of all, although the sample size in both experiments was sufficient for the confirmatory analyses, as the power analysis for Experiment 1 and the sensitivity analysis for Experiment 2 indicated, a larger sample size would certainly increase the power of the analyses. Second, for now, our results cannot be extrapolated to goals other than speed and accuracy, neither can they be generalized to other aspects of executive control than flexibility. Further research is needed to include the manipulation of other goals (e.g., categorization vs. individuation goals, cooperation vs. competition goals, high vs. low levels of motivation to control prejudice) and measure their impact on cognitive flexibility but also on different executive control processes.

Concluding Remarks

To sum up, the evidence presented in this paper illustrates that goals modulate the efficiency of executive control. Induced speed and accuracy goals influenced general task performance as well as the control of interference in the SCST, a switching paradigm that requires the categorization of social stimuli. The results from this study indicate the importance of considering different types of goals when conducting research on executive control, and evaluate not only the possible impact of goal maintenance processes, but also of goal disengagement and reengagement.

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FOOTNOTES

[1] We calculated the minimum recommended sample size for the confirmatory analysis, a 2 x 2 repeated measures ANOVA, using G*Power 3 (Faul et al., 2007). The within-subject factors were goal (speed vs. accuracy) and task switch (switch vs. no switch). For an effect size (Cohen's f) of 0.20, an alpha of .05 and power of .80, a minimum sample of 36 participants was required.

[2] The confirmatory and exploratory reaction time analyses of both experiments were repeated with two subject-specific cut-offs. Rather than removing RTs shorter than 200 ms and longer than 2000 ms, we removed RTs shorter than 200 ms and then RTs that were 2.5 and 3 standard deviations above and below the mean. The results of the analyses remained identical regardless of the type of cut-off criterion applied.

[3] To reduce the influence of the previous goal, the confirmatory analyses of both experiments were repeated removing the first 20% of trials of each block (i.e., 16 trials), instead of only the first trial. The results of these analyses were identical to those reported in this manuscript.

[4] The average completion time for each experimental block in Experiment 1 was approximately 04:50 minutes, with faster completion times for the blocks in which the speed goal was salient (04:44 minutes approximately) compared to the blocks in which the accuracy goal was salient (04:56 minutes approximately).

[5] The analyses of Experiment 2 were identical to the analyses of Experiment 1, and therefore no power analysis was conducted prior data collection. However, a post-hoc sensitivity analysis revealed that the minimum detectable effect size (Cohen's f) for a 2 x 2 repeated measures ANOVA (Goal x Task switch), with a sample size of 44 participants, an alpha of .05 and a power of .80, was .18. The smallest significant effect size (partial Eta-squared) reported in the confirmatory analyses of Experiment 2 was .30, which corresponds to a Cohen's f of .65.

[6] After trimming the data for RTs analysis, two participants had only one observation in one of the experimental conditions considered for the exploratory analysis (i.e., goal, task, repetition type, and task switch). The RTs analyses (both confirmatory and exploratory) were repeated excluding those participants, with no changes in the results.

[7] The average completion time for each experimental block in Experiment 2 was approximately 04:45 minutes, with faster completion times for the two consecutive blocks in which the speed goal was salient (04:37 minutes per block approximately) compared to the two consecutive blocks in which the accuracy goal was salient (04:54 minutes per block approximately).

Appendix

PROPORTION OF VALID OBSERVATIONS PER PARTICIPANT INCLUDED IN THE REACTION TIME CONFIRMATORY ANALYSES FOR THE CONDITIONS OF GOAL AND TASK SWITCH, AND SUMMARY OF EXPLORATORY ANALYSES

Table A. Proportion of Valid Observations per Participant Included in the Reaction Times Analyses of Experiment 1 and Experiment 2

	Accuracy goal				Speed goal			
	No switch		Switch		No switch		Switch	
	M (SD)	Range	*M (SD)*	Range	*M (SD)*	Range	*M (SD)*	Range
Experiment 1	88.46 (8.67)	57.25 – 98.32	84.25 (13.04)	34.91 – 99.17	89.70 (8.33)	62.07 – 99.16	84.94 (13.44)	40.35 – 99.16
Experiment 2	94.29 (6.62)	77.27 – 100	91.43 (9.39)	61.18 – 100	91.21 (9.44)	58.11 – 100	88.23 (10.59)	54.76 – 100

Note. Valid observations include the data points analysed after removing the first trial of each block, errors, and trials with reaction times shorter than 200 ms and longer than 2000 ms. The total number of trials per condition varied across participants due to the randomization of the stimuli.

Table B. Summary of ANOVAs Conducted for Reaction Times and Error Rates in Experiment 1 and in Experiment 2, Exploratory Analyses

	Experiment 1					Experiment 2				
	df	ANOVA reaction times		ANOVA error rates		*df*	ANOVA reaction times		ANOVA error rates	
		F	η_p^2	*F*	η_p^2		*F*	η_p^2	*F*	η_p^2
Goal	1, 44	52.08***	.54	5.22*	.11	1, 43	35.49***	.45	20.15***	.32
Task	1, 44	8.49**	.16	6.94*	.14	1, 43	3.64	.08	9.64**	.18
Task switch	1, 44	134.64***	.75	18.80***	.30	1, 43	135.03***	.76	40.25***	.48
Repetition type	2, 88	90.60***	.67	19.38***	.31	2, 86	80.76***	.65	2.63	.06
Goal x Task	1, 44	2.06	.04	0.22	.00	1, 43	0.84	.02	3.10	.07
Goal x Task switch	1, 44	0.06	.00	2.69	.06	1, 43	0.60	.01	7.54**	.15
Task x Task switch	1, 44	24.81***	.36	11.11**	.20	1, 43	6.29*	.13	2.04	.05
Goal x Repetition type	2, 88	0.49	.01	1.99	.04	2, 86	0.39	.01	1.00	.02
Task x Repetition type	2, 88	1.70	.04	1.09	.02	2, 86	0.54	.01	4.09*	.09
Task switch x Repetition type	2, 88	95.58***	.68	33.20***	.43	2, 86	50.71***	.54	10.12***	.19
Goal x Task x Task switch	1, 44	0.20	.00	0.09	.00	1, 43	0.06	.00	0.33	.01
Goal x Task x Repetition type	2, 88	1.19	.03	1.80	.04	2, 86	0.04	.00	4.05*	.09
Goal x Task switch x Repetition type	2, 88	0.12	.00	3.38*	.07	2, 86	0.77	.02	2.22	.05
Task x Task switch x Repetition type	2, 88	0.00	.00	4.40*	.09	2, 86	2.04	.05	1.35	.03
Goal x Task x Task Switch x Repetition Type	2, 88	0.00	.00	0.47	.01	2, 86	0.17	.00	0.00	.00

Note. *$p > .05$; ** $p > .01$; ***$p < .001$