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Brief article

Which cognitive tools do we prefer to use, and is that preference rational?

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ABSTRACT

This work aims to address the issue of which kind of cognitive tools we prefer, and whether this preference is rational. To do so, we proposed three experiments in which participants had to play the game *Guess Who?* by choosing between three tools that assisted them in three distinct cognitive functions (Working memory *vs.* Selective visual attention *vs.* Decision-making). In Experiment 3, additional tasks were proposed to assess participants' performance and meta-representations in working memory, selective visual attention and decision-making. Our findings indicate that participants preferred to use a cognitive tool assisting working memory over selective visual attention and decision-making. The meta-representation of participants' performance influenced the decision to use one cognitive tool over the others much more than individual performance itself. These results suggest that a search for effectiveness rather than efficiency, as well as the meta-representations of cognitive performance might be two key predictors of people's preference toward a cognitive tool.

1. Introduction

Among the diversity of tools we use in everyday life, we are more and more prone to use cognitive tools, defined as any external object that increases our cognitive skills (Osiurak, Navarro, Reynaud, & Thomas, 2018; Virgo, Pillon, Navarro, Reynaud, & Osiurak, 2017). The use of a cognitive tool is as an instance of use of external processing to avoid internal processing, a phenomenon called cognitive offloading (Kirsh & Maglio, 1994; Risko, Medimorec, Chisholm, & Kingstone, 2014; Sparrow, Liu, & Wegner, 2011; Wilson, 2002). In our societies, we are surrounded by those tools. Yet, we do not systematically use all of them, raising the critical issue of why some of them are adopted and others rejected. This work aims to address this issue, by exploring which kind of cognitive tools we prefer, and whether this preference is rational.

The issue of tool adoption has been extensively evaluated in the field of acceptance (Alexandre, Navarro, Reynaud, & Osiurak, 2018; Hornbæk, 2006), with a special emphasis on factors that cannot be considered as cognitive, such as age, education, gender, user characteristics or experience (Czaja et al., 2006; King & He, 2006; Venkatesh & Morris, 2000). However, to our knowledge, no research has investigated which cognitive functions people want to replace when using cognitive tools. This underexplored issue is of particular relevance if we consider the emergence of many new technologies that are designed to replace most of our cognitive skills without knowing which of them people want to replace. In this perspective, a huge number of cognitive functions could be studied (e.g., calculation skills, episodic memory). For the sake of feasibility, we decided to focus on three cognitive functions: working memory (storage and manipulation of task-relevant information); selective visual attention (selection of visual information); and decision-making (choice making among several possible alternatives).

Based on the literature, we made two clear predictions for two of the three aforementioned cognitive functions. First, it has been demonstrated that people tend to use tools as external memories (Henkel, 2014; Sparrow et al., 2011; Storm & Stone, 2015), suggesting that people should use off-loading tools that facilitate access to information thereby extending working memory skills. Second, evidence indicates that people like to choose, a characteristic that also exists in nonhuman animals (Iyengar & Lepper, 1999, 2000; Leotti, Iyengar, & Ochsner, 2010; Schwartz, 2004). Therefore, we hypothesized that people should not favor the use of a tool helping them in decision-making. Concerning selective visual attention, the prediction was less clear. Nevertheless, attentional processes being effortful, we predicted that people should be inclined to use tools assisting selective visual attention. Finally, we also intended to know if the choice of the tool is consistent with individuals' cognitive capacities or rather metacognitive representations of their performance.

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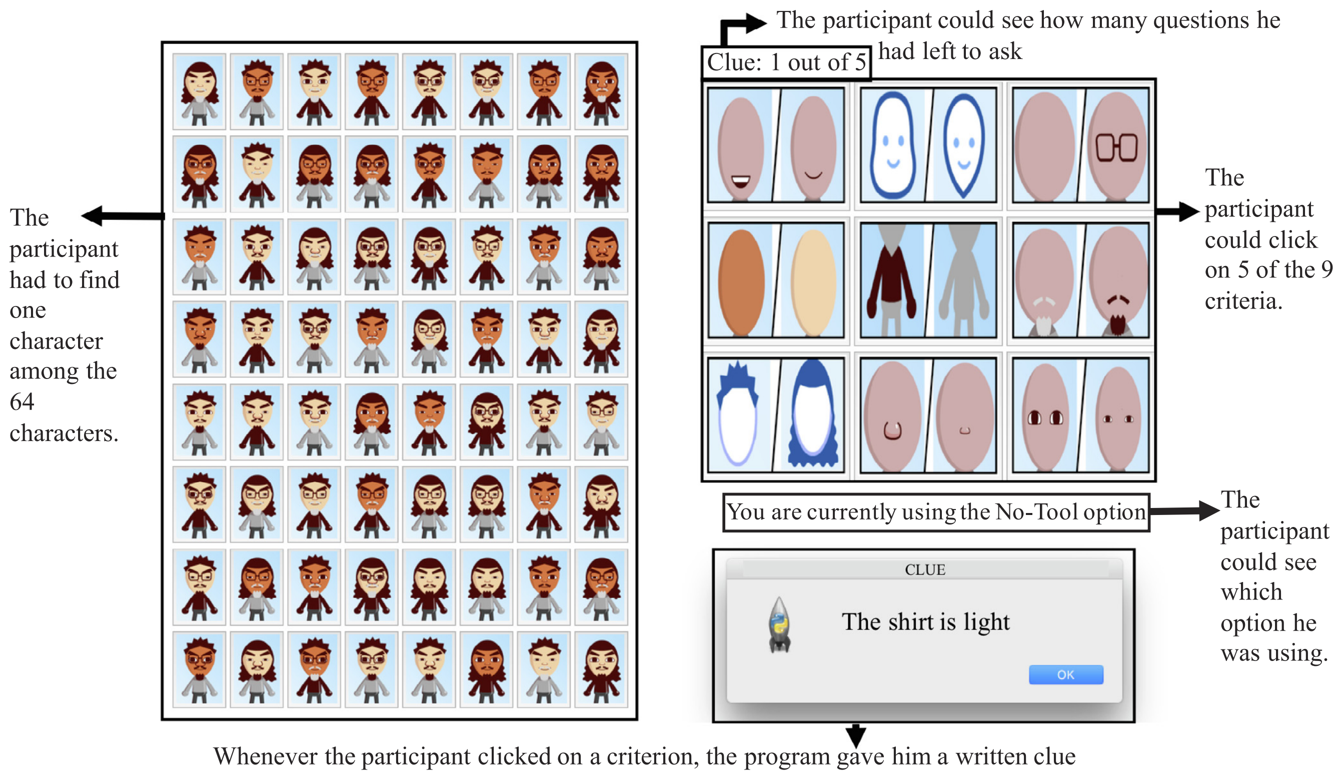

Fig. 1. The game, in the No-Tool option. Here, the program indicates the response to the question of a participant about the color of the shirt of the target character.

To test our predictions, we proposed three experiments involving 90 participants (n = 30 each). The task was a virtual version of the game *Guess Who?* allowing us to study the three aforementioned cognitive functions. In Experiment 1, participants were confronted with three tools that assisted them in three cognitive functions (Working memory, labeled as Note option, *vs.* Selective visual attention, labeled as Fuzzy option, *vs.* Decision-making, labeled as Choice option). They also had the choice of using none of these tools (i.e., an additional "No-Tool" option) in order to explore whether participants preferred to use a tool over performing the task without any tool. In Experiment 1, a relatively high number of choices was presented (i.e., 30) in order to ensure that participants' preferences reflected a long-term preference for a specific option, and not just a short-term preference. The same procedure was employed in Experiment 2 to confirm the results of Experiment 1. Simply, the task was shorter to examine whether the long-term preferences found in Experiment 1 could also be observed at short term. Moreover, participants had to only choose among the three tools (i.e., Note, Fuzzy and Choice options). Finally, the procedure was the same in Experiment 3 as in Experiment 2, except that the version of task given was moderately longer. This was done to confirm once again our results. Moreover, additional tasks were proposed to assess participants' performance in working memory, selective visual attention and decision-making. Participants were also measured on the meta-representations of their performance on these additional tasks.

2. Methods

2.1. Participants

Ninety participants (51 women) took part in Experiments 1–3 (n = 30 for each). They were all undergraduate students in cognitive science at the University of Lyon ($M_{Exp.\ 1} = 23 \pm 3.5$; $M_{Exp.\ 2} = 22.5 \pm 2.4$; $M_{Exp.\ 3} = 22.1 \pm 1.8$). Each participant gave informed consent to the study.

2.2. Materials and procedure common to experiments 1–3

2.2.1. Materials

The task developed for Experiments 1–3 was a virtual version of the game *Guess Who?* In the original game, the goal is to guess the character chosen by the opponent, by asking questions about his physical appearance. In our virtual version, participants had to find a target character hidden among 64 other characters, by asking five questions about nine criteria of physical appearances. Three of these criteria concerned the shape of the face or one of its attributes: opened/closed mouth, rounded/pointed face, and with/without glasses. Three other criteria concerned the color of a physical attribute: light/dark skin, light/dark shirt, and light/dark mustache. The last three criteria concerned the size of a physical attribute: short/long hair, small/big nose, and small/big eyes. Each game had unique solutions, but some criteria were more advantageous than others for a specific game. However, in each experiment, each criterion was presented in 50% of games as advantageous and in 50% of games as disadvantageous. Each grid of 64 characters was constructed by probabilities. For example, for the eye criterion, characters could be divided into 90% of big eyes and 10% of small eyes, while, for the shirt criterion, characters could be divided into 50% of light shirts and 50% of dark shirts. Each character in the grid could vary according to the nine criteria described above, giving 512 possible combinations of characters.

2.2.2. Procedure

Because we were interested in the kind of cognitive tools participants preferred, in the games (i.e., trials) participants could choose among three tool options (Experiments 2–3) or among three tool options and the No-Tool option (Experiment 1) to solve the game (i.e., free-use games). For each free-use game, participants could select with the mouse one of the different options by clicking on the name of the option. The order of presentation of the options was counterbalanced between participants. After the option chosen, a grid of 64 characters appeared on the left of the screen, and the nine criteria on the right of the screen (Fig. 1). The display of criteria remained identical for a given participant during the task but was counterbalanced between participants. Participants could click on one of the criteria, leading them to obtain a clue written on the screen about the target character (Fig. 1). They could have up to five clues to identify the target character. Based on the five clues, they could guess and indicated which was the target character by clicking on him. They were informed as to whether their response was correct or not, marking the end of the game, and a new game was proposed to them with, again, the selection of different options. Participants were told they were free to choose any option and that they should feel free to select one option more often than the others if they began to prefer it. We also introduced forced-use games to be sure that participants understood what was the functionality of each tool. In these forced-use games, participants were forced to play the game with one of the options.

2.3. Differences between the four options

Contrary to the real version of the game *Guess Who?*, participants could not hide progressively the irrelevant characters. Nevertheless, four (or three in Experiments 2–3) options were offered to help them. In the *No-Tool option*, participants had to play the game without any particular help. In the *Note option*, a tool assisted participants' working memory. Participants had not to memorize the clues about the target character because there was a reminder written on the screen mentioning the clues progressively obtained. In the *Fuzzy option*, a tool assisted participants' selective visual attention, by reducing the amount of visual information on the screen. Thus, if participants clicked on the hair criterion and the clue was 'short hair', all the characters with long hair were blurred. This help was not cumulative. When participants clicked on a second criterion, only the characters targeted by the new criterion were blurred, but not those targeted by the previous one. In the *Choice option*, a tool assisted participants' decision-making, by indicating the optimal list of the five most advantageous criteria (available until the end of the game) to find the target character without giving the response associated to each criterion. For example, participants could be advised to click, among others, on the criterion of the mouth, but no information was provided about whether the target character had the mouth open or closed.

2.4. Differences between the three studies

Fig. 2 summarizes the methodological differences between the three experiments. In Experiment 1, participants were presented with four options (No-Tool, Note, Fuzzy, and Choice) to complete 34 games in the following order: four forced-use games, and 30 free-use games (i.e., 30 preferences to give). In Experiment 2, participants were presented with three options (Note, Fuzzy, and Choice) to complete 12 games in the following order: Three forced-use games, three free-use games, three forced-use games, and three free-use games (i.e., six preferences to give). In Experiment 3, participants were presented with three options (Note, Fuzzy, and Choice) to complete 18 games in the following order: three forced-use games, six free-use games, three forced-use games, and six free-use games (i.e., 12 preferences to give).

In Experiment 3, we also collected participants' performance (cognitive score) on tasks assessing three cognitive functions: working memory (Baddeley's dual task interference and a reverse memory span), selective visual attention (the Bells test (Gauthier, Dehaut, & Joanette, 1989) and the Symbol cancellation test (Lowery, Ragland, Gur, Gur, & Moberg, 2004)) and decision-making, i.e. their aversion/attraction to risky decision (Iowa gambling task (Bechara, Damasio, Damasio, & Anderson, 1994; Brevers et al., 2012) and the game of dice task (Brand et al., 2002)). In addition, we measured participants' meta-representations of their performance on the three aforementioned tasks by asking them, before each task, to indicate on a scale from 0 to 100, how good they thought they were in performance compared to the people of their age. Thus, each participant had two cognitive scores in working memory, selective visual attention and decision-making, as well as one estimation of their own performance (metacognitive score) for each task. To obtain only one cognitive score and one metacognitive score for each cognitive function, we used the following procedure.

2.4.1. Cognitive scores

We computed for each participant a standard z-score for each task. Then, we averaged the two cognitive scores corresponding to the two tasks assessing the same cognitive function to obtain a composite cognitive score for each cognitive function. The higher the cognitive score was, the better the participant was in working memory, in selective visual attention, and in decision-making (i.e., safe strategy).

2.4.2. Metacognitive scores

We first translated the z-scores obtained for each cognitive score into percentiles for each participant. Then, we computed the difference between the estimation given by each participant for each task and the cognitive score transformed into percentiles (i.e., Estimation *minus* Percentile cognitive score). Finally, we averaged the two differences corresponding to the two tasks assessing the same cognitive function to obtain a metacognitive score for each cognitive function. A positive metacognitive score indicated an overestimation of performance, and a negative score an under-estimation of performance.

3. Results

3.1. Experiment 1

3.1.1. Correct responses

As summarized in Table 1, participants made 23%, 57%, 10%, and 20% of correct responses in forced-use games with No-Tool, Note, Fuzzy, and Choice, respectively. A non-parametric, Friedman ANOVA was conducted on the number of correct responses with the factor OPTION (No-Tool, Note, Fuzzy, and Choice) as within-subject factor. This analysis revealed a significant effect of OPTION ($\chi^2 = 18.2$, $N = 30$, $df = 3$, $p < .001$) indicating that participants were more successful in Note than in other options. Wilcoxon rank-sum tests showed that Note > Zero ($p = .01$), Note > Fuzzy ($p < .001$), and Note > Choice ($p = .02$). In free-use games, the better performance found in Note disappears, Choice being the option with the best performance (51%, 44%, 39% and 71% of correct responses with No-Tool, Note, Fuzzy, and Choice).

3.1.2. Response time in forced-use games

An ANOVA was conducted on response time with the factor OPTION (No-Tool, Note, Fuzzy, and Choice) as within-subject factor. This analysis revealed a significant effect of OPTION ($F = 4.89$, $p = .003$). Bonferroni corrected t-tests revealed that participants were faster with Fuzzy ($M = 97$ s; $SE = 12$ s) rather than No-Tool ($M = 133$ s; $SE = 16$; $p < .01$) and Note option ($M = 118$ s; $SE = 13$ s; $p < .02$). There was no other significant difference (Choice: $M = 102$ s; $SE = 9$ s).

3.1.3. Group preference

A non-parametric ANOVA was conducted on the number of preferences with the factor OPTION (No-Tool, Note, Fuzzy, and Choice) as within-subject factor. As illustrated in Fig. 3, this analysis revealed a significant effect of OPTION ($\chi^2 = 23.17$, $N = 30$, $df = 3$, $p < .001$) indicating that Note was preferred over other options (Wilcoxon rank-sum: Note > No-Tool, $p < .001$; Note > Fuzzy, $p < .01$; Note > Choice, $p = .054$; Fuzzy > No-Tool, $p < .01$; Choice > No-Tool, $p < .01$).

3.1.4. Individual preference

We used a Fisher's exact test to specify the preferences associated to each participant ($p < .01$). This analysis confirmed the results

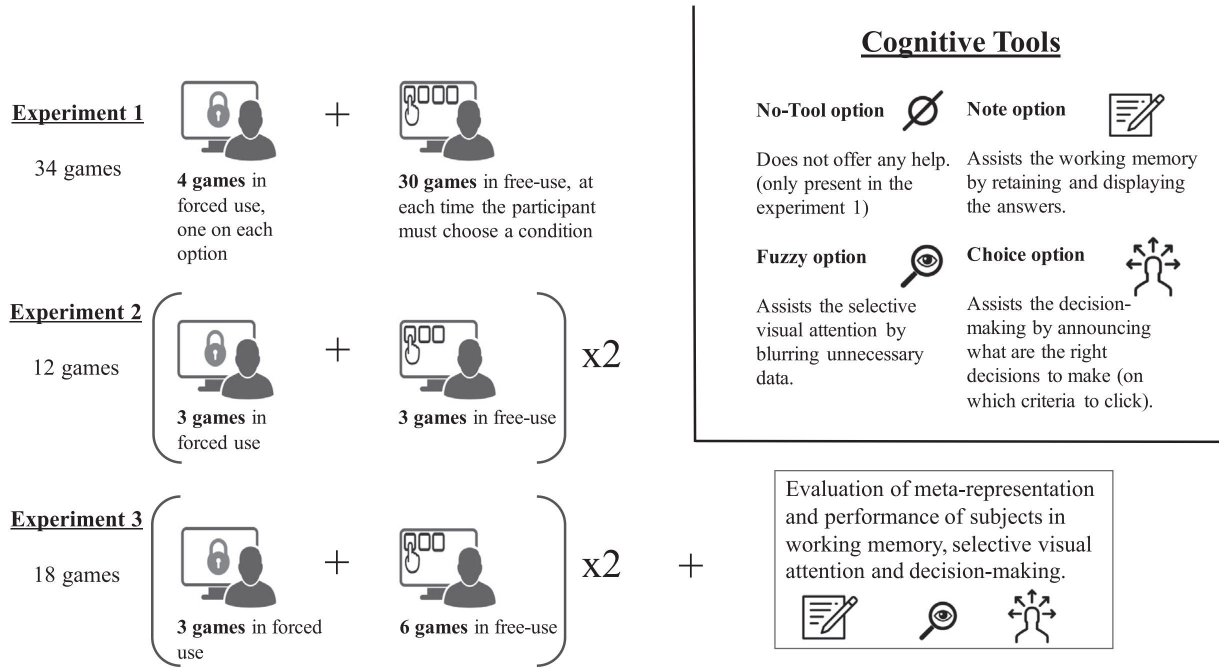

Fig. 2. Overview of the three experiments.

obtained at the group level by showing that 14 participants mainly chose Note (47%), 7 participants Choice (23%), 4 participants Fuzzy (13%) and 1 participant No-Tool (3%). The remaining 4 participants had no preference (13%).

3.1.5. Link between performance and preference

Point-biserial correlations were computed between the dichotomous variable correct/incorrect response in each option of forced-use games and the number of choices made in the same option in the subsequent free-use games. As shown in Table 1, no significant correlation was observed for No-Tool (p = .81), Note (p = .11), Fuzzy (p = .98), and Choice (p = .15). Note that we also calculated correlations between preference in free-use games and response time in forced-use games. Again, no significant correlation was found (all $p > .05$).

3.2. Experiment 2

3.2.1. Correct responses

As summarized in Table 1, in the first three forced-use games, participants made 67%, 20% and 30% of correct responses with Note, Fuzzy, and Choice options. A non-parametric, Friedman ANOVA was conducted on the number of correct responses with the factor OPTION (Note, Fuzzy, and Choice) as within-subject factor. This analysis revealed a significant effect of OPTION (χ^2 = 15.52, N = 30, df = 2, $p < .001$) indicating that participants were more successful in Note than in other options. Wilcoxon rank-sum tests showed that Note > Fuzzy ($p < .001$), and Note > Choice (p = .02). This better performance found in Note disappears in the second three forced-use games (57%, 43% and 67%, respectively) as confirmed by a non-parametric, Friedman ANOVA conducted on the number of correct responses with

Table 1
Percentage of correct responses for each option, and correlations between performance in each option (forced-use games) and the number of subsequent choices in that option (free-use games).

		Experiment 1		Experiment 2				Experiment 3			
		Forced-use 4 games	Free-use 30 games	Forced-use 3 games	Free-use 3 games	Forced-use 3 games	Free-use 3 games	Forced-use 3 games	Free-use 6 games	Forced-use 3 games	Free-use 6 games
No-tool option	Percentage of correct responses	23%	51%								
	Correlation between performance (forced-use games) and choices (subsequent free-use games)	$r = -0.05$ p = .81									
Note option (working memory)	Percentage of correct responses	57%	44%	67%	53%	57%	40%	40%	41%	60%	49%
	Correlation between performance (forced-use games) and choices (subsequent free-use games)	r = .29 p = .11		r = .24 p = .20		$r = -0.03$ p = .87		r = .03 p = .88		$r = -0.04$ p = .82	
Fuzzy option (selective visual attention)	Percentage of correct responses	10%	39%	20%	43%	43%	33%	60%	30%	43%	21%
	Correlation between performance (forced-use games) and choices (subsequent free-use games)	r = .01 p = .98		r = .07 p = .70		r = .17 p = .38		$r = -0.3$ p = .11		r = .26 p = .17	
Choice option (decision-making)	Percentage of correct responses	20%	71%	30%	65%	67%	62%	7%	49%	40%	46%
	Correlation between performance (forced-use games) and choices (subsequent free-use games)	r = .27 p = .15		r = .16 p = .41		r = .15 p = .44		r = .01 p = .95		$r = -0.14$ p = .47	

Correlations are point-biserial correlations between performance in each option (forced-use games) and the number of subsequent choices in that option (free-use games). For Experiments 2 and 3, correlations only concern the free-use games that are presented just after the forced-use games.

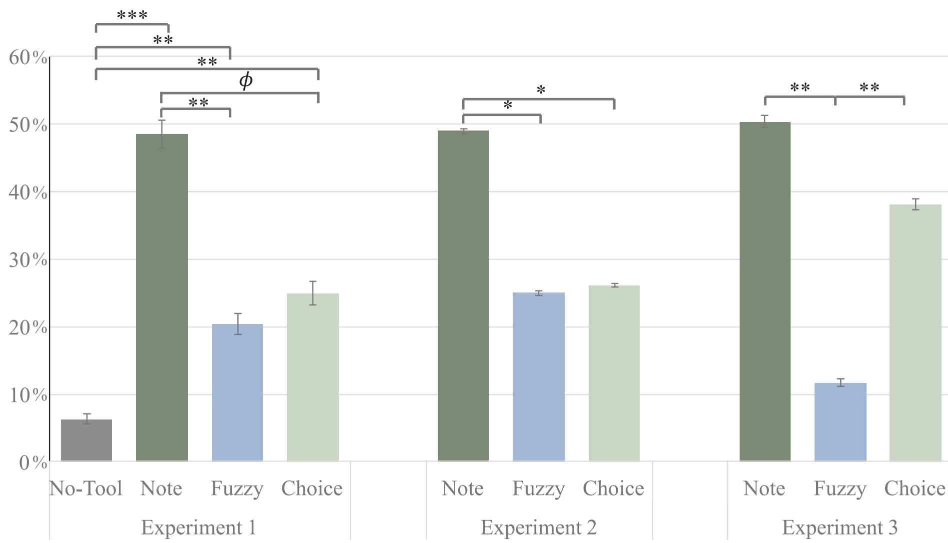

Fig. 3. Participants' choice (in percentage) for each option, for each experiment. In Experiment 1, there were 30 choices; in Experiment 2, there was 6 choices; In Experiment 3, there was 12 choices. Bars are error bars. ϕ $p = .054$, $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

the factor OPTION (Note, Fuzzy, and Choice) as within-subject factor. This analysis revealed no significant effect of OPTION ($\chi^2 = 3.7$, $N = 30$, $df = 2$, $p = .15$). Wilcoxon rank-sum tests showed that there was no significant difference between Note and Fuzzy ($p = .30$), Note and Choice ($p = .42$), and Choice and Fuzzy ($p = .13$). In the first three free-use games, participants made 53%, 43%, and 65% of correct responses with Note, Fuzzy, and Choice options, and in the second three free-use games 40%, 33% and 62%, respectively.

3.2.2. Response time in forced-use games

An ANOVA was conducted on response time with the factor OPTION (Note, Fuzzy, and Choice) as within-subject factor. Concerning the first three forced-use games, this analysis revealed no significant effect of OPTION ($F = 2.98$, $p > .05$; Note: $M = 110$ s; $SE = 14$ s; Fuzzy: $M = 95$ s; $SE = 13$ s; Choice: $M = 91$ s; $SE = 9$ s). Again, no significant effect of OPTION was found for the second three forced-use games ($F = 2.49$, $p > .05$; Note: $M = 98$ s; $SE = 10$ s; Fuzzy: $M = 80$ s; $SE = 7$ s; Choice: $M = 88$ s; $SE = 10$ s).

3.2.3. Group preference

A non-parametric ANOVA was conducted on the number of preferences with the factor OPTION (Note, Fuzzy, and Choice) as within-subject factor. As illustrated in Fig. 3, this analysis revealed a significant effect of OPTION ($\chi^2 = 10.32$, $N = 30$, $df = 2$, $p < .01$) indicating that Note was preferred over other options (Wilcoxon rank-sum: Note > Choice, $p < .05$; Note > Fuzzy, $p < .05$).

3.2.4. Individual preference

We used a Fisher's exact test to specify the preferences associated to each participant ($p < .01$). This analysis showed that 3 participants mainly chose Note (10%), 3 participants Choice (10%), and 2 participants Fuzzy (7%). The remaining 22 participants had no preference (73%). The discrepancy between these results (i.e., no clear individual preference for Note) and those obtained above at the group level (i.e., preference for Note) can be explained by the relatively low number of choices participants had to make (i.e., only 6 choices, making difficult the proportion of significant results at the individual level).

3.2.5. Link between performance and preference

Point-biserial correlations were computed between the dichotomous variable correct/incorrect response in each option of the first forced-use games and the number of choices made in the same option in the subsequent free-use games. As shown in Table 1, no significant correlation was observed for Note ($p = .20$), Fuzzy ($p = .70$), and Choice ($p = .41$). The same analysis was carried out with the second forced-use games and the number of choices made in the same option in the subsequent free-use games (Table 1). Again, no significant correlation was observed for Note ($p = .87$), Fuzzy ($p = .38$), and Choice ($p = .44$). Note that we also calculated correlations between preference in free-use games and response time in forced-use games for each part of the experiment (first and second, see above). Again, no significant correlation was found (all $p > .05$).

3.3. Experiment 3

3.3.1. Correct responses

As summarized in Table 1, in the first three forced-use games, participants made 40%, 60% and 7% of correct responses with Note, Fuzzy, and Choice options. A non-parametric, Friedman ANOVA was conducted on the number of correct responses with the factor OPTION (Note, Fuzzy, and Choice) as within-subject factor. This analysis revealed a significant effect of OPTION ($\chi^2 = 17.04$, $N = 30$, $df = 2$, $p < .001$) indicating that participants were less successful in Choice than in other options. Wilcoxon rank-sum test showed that Choice < Note ($p = .01$), and Choice < Fuzzy ($p < .001$). There was no significant difference between Note and Fuzzy ($p = .15$). This lesser performance found in Choice disappears in the second three forced-use games (60%, 43% and 40%, respectively). A non-parametric ANOVA was conducted on the number of correct responses with the factor OPTION (Note, Fuzzy, and Choice) as within-subject factor. This analysis revealed no significant effect of OPTION ($\chi^2 = 2.95$, $N = 30$, $df = 2$, $p = .22$). Wilcoxon rank-sum test showed that there was no significant difference between Note and Fuzzy ($p = .28$), Note and Choice ($p = .21$), and Choice and Fuzzy ($p = .73$). In the first six free-use games, participants made 41%, 30%, and 49%, of correct responses with Note, Fuzzy, and Choice options, and in the second six free-use games 49%, 21% and 46%, respectively.

3.3.2. Response time in forced-use games

An ANOVA was conducted on response time with the factor OPTION (Note, Fuzzy, and Choice) as within-subject factor. Concerning the first three forced-use games, this analysis revealed no significant effect of OPTION ($F = 0.84$, $p > .05$; Note: $M = 112$ s; $SE = 8$ s; Fuzzy: $M = 105$ s; $SE = 6$ s; Choice: $M = 102$ s; $SE = 7$ s). Again, no significant effect of OPTION was found for the second three forced-use games ($F = 1.45$, $p > .05$; Note: $M = 102$ s; $SE = 6$ s; Fuzzy: $M = 95$ s;

$SE = 6$ s; Choice: $M = 104$ s; $SE = 7$ s).

3.3.3. Group preference

A non-parametric ANOVA was conducted on the number of preferences with the factor OPTION (No-Tool, Note, Fuzzy, and Choice) as within-subject factor. As illustrated in Fig. 3, this analysis revealed a significant effect of OPTION ($\chi^2 = 17.80$, $N = 30$, $df = 2$, $p < .001$) indicating that Note was preferred over other options (Wilcoxon rank-sum: Note > Fuzzy, $p < .01$; Choice > Fuzzy, $p < .01$).

3.3.4. Individual preference

We used a Fisher's exact test to specify the preferences associated to each participant ($p < .01$). This analysis confirmed the results obtained at the group level by showing that 12 participants mainly chose Note (40%), 9 participants Choice (30%), and 2 participants Fuzzy (7%). The remaining 7 participants had no preference (23%).

3.3.5. Link between performance and preference

Point-biserial correlations were computed between the dichotomous variable correct/incorrect response in each option of the first forced-use games and the number of choices made in the same option in the subsequent free-use games. As shown in Table 1, no significant correlation was observed for Note ($p = .88$), Fuzzy ($p = .11$), and Choice ($p = .95$). The same analysis was carried out with the second forced-use games and the number of choices made in the same option in the subsequent free-use games (Table 1). Again, no significant correlation was observed for Note ($p = .82$), Fuzzy ($p = .17$), and Choice ($p = .47$). Note that we also calculated correlations between preference in free-use games and response time in forced-use games for each part of the experiment (first and second, see above). Again, no significant correlation was found (all $p > .05$).

3.3.6. Preference and cognitive score

The correlations obtained between preferences and performance at cognitive score are provided in Table 2. This analysis revealed a negative significant correlation between the decision-making score and preference for Note, and a positive significant correlation between the decision-making score and preference for Choice.

3.3.7. Preference and metacognitive score

The correlations obtained between preferences and metacognitive score are provided in Table 2. We only found negative significant correlations between the preference for an option and the corresponding metacognitive score. To deepen the statistical analysis of these last three correlations, we made linear regressions that confirmed the uniqueness of the link between the preference for each option and the corresponding metacognitive score (Table 3).

Table 2
Links between different options (Note, Fuzzy and Choice) and the cognitive score on the hand and the metacognitive score on the other hand.

	Pearson correlations		
	Note option	Fuzzy option	Choice option
Cognitive score			
Working memory	0.081	−0.049	−0.052
Selective visual attention	−0.189	0.275	0.021
Decision-making	−0.432**	−0.085	0.497**
Metacognitive score			
Working memory	−0.362*	0.120	0.295
Selective visual attention	0.100	−0.364*	0.126
Decision-making	0.350	0.151	−0.454*

* $p < .05$.
** $p < .01$.

Table 3
Linear regression showing the significant link between different cognitive tools (Note, Fuzzy and Choice option) and the metacognitive score in working memory, selective visual attention and decision-making.

	Linear regression		
	ß	t	p
Note option			
Metacognitive score in working memory $R^2_{adj} = 0.100$, F = 4.216, p = .049	−0.095	−2.053	–*
Fuzzy option			
Metacognitive score in selective visual attention $R^2_{adj} = 0.101$, F = 4.275, p = .048	−0.060	−2.068	–*
Choice option			
Metacognitive score in decision-making $R^2_{adj} = 0.178$, F = 7.263, p = .012	−0.071	−2.695	–**

* $p < .05$.
** $p < .01$.

4. Discussion

The first key finding is that people prefer to use a cognitive tool than no tool, and particularly a cognitive tool assisting working memory rather than selective visual attention and decision-making. This is consistent with previous work demonstrating that people are very prone to using off-loading, cognitive tools as external memories (Henkel, 2014; Risko & Gilbert, 2016; Sparrow et al., 2011; Storm & Stone, 2015). The interesting issue is why this kind of cognitive tool might be preferred. A first possibility is that participants were simply better using the Note option. Consistent with this, we found that, in the first forced-use games, participants were generally better using the Note option than the Fuzzy and Choice options. However, this interpretation remains delicate because, after prolonged use, these differences disappeared, participants improving themselves with all the cognitive tools. In addition, we did not find any significant correlation between performance in forced-use games and preference in free-use games (see below for more discussion on this aspect). A second possibility is that people "prefer to acquire information just as it is needed, rather than holding an item in memory" (Hayhoe, 2000, p. 50), a hypothesis called the minimum memory hypothesis (see also Ballard, Hayhoe, & Pelz, 1995; for an alternative view, see Gray, Sims, Fu, & Schoelles, 2006). Another possibility can be offered in light of the classical effectiveness/efficiency distinction (Frojkaer, Hertzum, & Hornbaek, 2000). Participants could have the metacognitive experience to reach the same level of performance by spending more time to look for the target character instead of using the Fuzzy option or to make the right decision instead of using the Choice option. Said differently, they could have perceived both the Fuzzy option and the Choice option as a help to be more efficient (i.e., gaining time/effort) but not more effective. By contrast, they could have thought that if they forgot the clues previously obtained, their level of performance could decrease dramatically. In this context, only the Note option allowed them to be more effective. These results suggest that people might favor perceived effectiveness over efficiency, corroborating previous work in the field of tool acceptance (Davis, Bagozzi, & Warshaw, 1989; Dillon & Morris, 1999). Further research is needed to explore this possibility, because we also found that many participants preferred to use the Choice option. This aspect suggests that the potential preference for effectiveness over efficiency might be subject to inter-individual variability, confirming models supporting the hypothesis of different user profiles (e.g., utilitarian *vs.* hedonistic; Van Der Heijden, 2004).

The second key finding is that the meta-representation of participants' performance influences the decision to use one cognitive tool over another much more than performance itself, corroborating previous work on cognitive offloading and metacognition (Dunn & Risko, 2016; Gilbert, 2015; Risko & Dunn, 2015; Risko & Gilbert, 2016). The less we feel confident for a given cognitive function, the more we choose a tool assisting this cognitive function, regardless of our performance level. This finding provides an alternative to the aforementioned efficiency/effectiveness hypothesis to explain the inter-variability observed in our three experiments for the different cognitive tools. More specifically, meta-representations could be the main engine of tool acceptance, leading participants to choose the best cognitive tool they could need based on an estimation of their own skills without tools. This interpretation opens interesting avenues in the field of tool acceptance where classical models generally overlook the meta-representational level, instead focusing on how people perceive the efficiency/effectiveness of a tool.

The third key finding is that participants' performance does not impact the subsequent preference for a given tool. It has been suggested that mixtures of perceptual-motor and cognitive resources are adjusted on the basis of their cost-benefits tradeoffs for interactive behavior (Gray et al., 2006; see also Kool, McGuire, Rosen, & Botvinick, 2010). This on-line adjustment is very close to the concept of metacognitive experiences, one of the two components of metacognition, the other being meta-representations (also called metacognitive beliefs; Risko & Gilbert, 2016). The absence of link between performance and preference seems to indicate that preference is more influenced by meta-representations than metacognitive experiences. Nevertheless, this interpretation remains to be taken with caution because much more research is needed to generalize our results to other tasks and cognitive tools.

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