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Neuropsychologia 43 (2005) 1858–1869

NEUROPSYCHOLOGIA

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Task alternation cost without task alternation: Measuring intentionality

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Received 26 July 2003; received in revised form 2 March 2005; accepted 11 March 2005
Available online 11 April 2005

Abstract

A behavioral dissociation between intention and action was demonstrated by patient AF who sustained damage to the left-hemisphere including the basal ganglia. The patient was tested in a task switching paradigm involving two choice reaction-time tasks: SIZE (small/large) and SHAPE (circle/square). The last block in each of the two sessions involved only one task. AF switched tasks reasonably well in the first 40 trials, but unlike her matched control group, in all the remaining trials when two tasks were involved, she performed only the SIZE task. Interestingly, although no task switching took place, AF continued to demonstrate behaviorally her intention to switch tasks. First, she exhibited "task alternation cost", poorer performance relative to instructed single-task trials. Second, shifting to an instructed single-task condition was accompanied by an initial response slowing, indicating a change in goal-state. Finally, when instructed to switch tasks, AF demonstrated the "task-congruency effect", indicating interference from the instructed but competing stimulus–response mapping. Two groups of university students were instructed to perform only the SIZE task, after initial switching, either while ignoring the SHAPE cues ("Ignore") or while being prepared for the SHAPE task only when the cue appeared in red, which never happened ("Attend color"). AF's performance resembled the one of the "Attend color" group and not the "Ignore" group. The results indicate that AF had a partially activated intention to switch tasks. The implications to intentionality and task switching theory are discussed.

Keywords: Task switching; Basal ganglia; Intention; Action; Behavioral measurement

According to The American Heritage Dictionary (1992), intention is defined as "an aim that guides an action" and also as "the state of one's mind at the time one carries out an action". This state of mind can be inferred in one of two ways (Searle, 1983). In the first, 'intentionality', i.e., the intention formed prior to the action, can be identified, for example, by an explicit report. In the other, termed 'intention in action', the intention is inferred from an observed act. This latter form is based on the assumptions, made above that there are no actions without intentions.

In spite of the above, there are two notable dissociations between intention and action. One form of dissociation, which is not in the focus of the present work, concerns conditions in which there is goal pursuit without intention. This dissociation is attributed to a lack of consciousness of the intention (e.g., Bargh, Gollwitzer, Lee-Chai, Brandollar, & Trotschel, 2001). The second form of dissociation, known as "abulic dissociation", is in the focus of the present study. It concerns conditions in which an intention is not followed by its appropriate action. Examples of this can be seen in children and patients with frontal lesions, who may act inappropriately despite verbally expressing their intention to do a given task and correctly answering knowledge questions about the task rules (e.g., Burgess, Veitch, de Lacy Costello, & Shallice, 2000; Dempster, 1992; Diamond, 1991; Harnishfeger & Bjorklund, 1993; Luria, 1961; Milner, 1963; Zelazo & Reznick, 1991). Related terms include "goal neglect" (Duncan, Emslie, Williams, Johnson, & Freer, 1996) and "strategy application disorder" (Shallice & Burgess, 1991).

Abulic dissociation is most often seen in the discrepancy between a verbally described intention and the actual performance (Goldin-Meadow, Alibali, & Church, 1993; Karmiloff-Smith, 1992; Zelazo & Reznick, 1991). It is rarer to find reports in which the intention can be inferred from

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0028-3932/$ – see front matter © 2005 Published by Elsevier Ltd.
doi:10.1016/j.neuropsychologia.2005.03.010

actual performance. One of these rare examples involves the dissociation between looking and reaching found in Piaget's (1954) A-not-B task. In this task, an object is hidden at one of two locations (A) and then retrieved by the infant. The object is then moved to a different location (B). A search at 'A' on the post-switch (B) trials is defined as an A-not-B error. According to Diamond (1985), infants occasionally look towards the correct location at the very same moment that they are reaching perseveratively. This, however, occurs in only about 1% of children (see Zelazo & Frye, 1996, for review).

1. The present study

In spite of their rarity, cases of abulic dissociation in which intention is inferred from action are very important theoretically. This is due to the shortcomings of verbal reports (Nisbett & Wilson, 1977), such as lack of access to one's state of mind, dependence on verbal abilities and insight and being subjected to demand characteristics. Another important implication is that goal activation may not be all-or-none, but be graded in nature, thus generating some behaviors that accord with the task requirements.

In this paper we report a case of a brain-damaged patient, AF, who demonstrated an abulic dissociation between intention and action in task performance, i.e., in her behavior rather than by verbal report. The present report is also interesting for its theoretical implications concerning the behavioral markers used here to measure intention. Patient AF was asked to switch between two reaction-time tasks: classifying an object according to its size (small or large) or its shape (circle versus square, see Fig. 1). In addition, there was a block of trials involving only one task at the end of each experimental session.

AF switched tasks reasonably well in the first 40 trials of Session 1, but in all the remaining trials in which two tasks were involved, she performed only the SIZE task. Interestingly, although no task switching took place, AF demonstrated behaviorally her partial intention to switch tasks, which was seen in several markers, described below. AF's unique performance was neither found among a

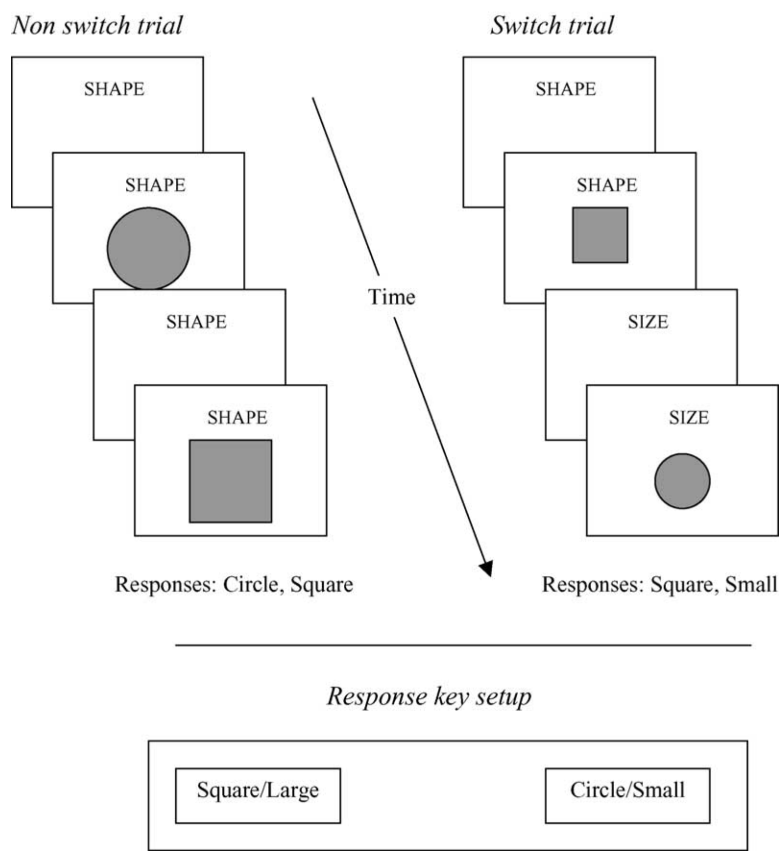

Fig. 1. Schematic illustration of the paradigm. The left side of the figure displays the sequence of events in the non-switch trials where a SHAPE task trial was followed by another SHAPE task trial. The right side of the figure refers to the switch trials where a SHAPE task trial was followed by a SIZE task trial. The stimuli were filled in white color and were either a small/large circle or a small/large square. The task-cues were the Hebrew equivalents of the words SIZE and SHAPE. They were presented 1° above the position where the target stimulus would have been presented. Responses were collected with a standard keyboard attached to a laptop computer. "SMALL" and "CIRCLE" responses were mapped to the right key ("L"), and "LARGE" and "SQUARE" responses were mapped to the left key ("J"). In order to help AF remembering the key assignment, we placed stickers with the first letter of the relevant attribute on the keys. Due to right-sided hemiparesis, AF used her left hand for responding. Each trial consisted of: (1) a presentation of an instructional task-cue (the Hebrew equivalent of either the word "SIZE" or the word "SHAPE") for a varied cue-target-interval of either 116 or 1016 ms and (2) a presentation of the target stimulus below the instructional cue until a response was given. The constant response cue interval was 2032 ms and 400 Hz beeps for 100 ms signaled errors.

gender–age–education matched control group nor among groups of university students who were asked to perform the SIZE task only.

2. Method

2.1. The patient

AF, a 53-year-old right-handed woman, with 11 years of education, was tested 3 months following the first-event ischemic infarction in the territory of the left middle cerebral artery, involving left parietal and capsular-putaminal regions (see Fig. 2).

AF's performance on the standardized Loewenstein Occupational Therapy Cognitive Assessment (LOTCA; Itzkovich, Averboch, Elazar, & Katz, 1990) revealed difficulties in categorization and problem solving. Shifting capacity was impaired and a tendency to perseverate was noted. In contrast, performance of the spatial perception, motor praxis, and visuomotor organization subtests of the LOTCA was intact. AF had aphasic language disturbances typical of conduction aphasia. Her speech revealed frequent paraphasic (mainly phonological) errors and naming difficulties and was accompanied by frequent gestures. She understood well spoken and written words and short sentences, but had difficulties with longer phrases, most probably reflecting attenuated retention span for auditory-verbal material. These problems did not affect her ability to comprehend the experimental instructions and to understand the written verbal cues as tested at the end of each of the two sessions.

A matched control group—Eight healthy control women were matched to AF in age and years of education (ages 51–54 years, education 11–13 years) were given the same instructions as AF did.

The "Ignore" group—Ten university students were told to switch tasks during practice and to perform the SIZE task thereafter like AF's first session.

The "Attend color" group—Nine additional students were given similar instructions but were asked to perform the SHAPE task if the appropriate task-cue was presented in red, something which never happened.

2.2. Procedure

For AF, the experiment was run in two identical sessions, separated by 5 days, with each session lasting approximately

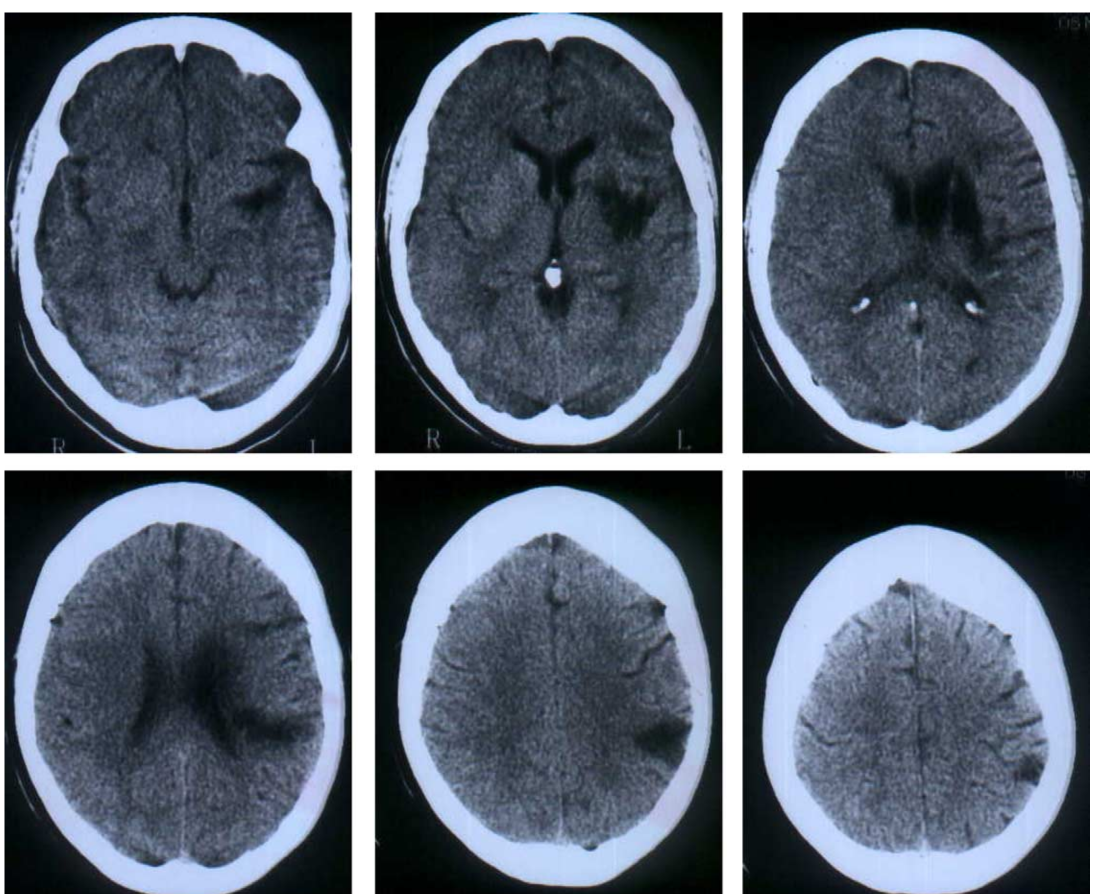

Fig. 2. Patient AF's follow-up CT scan performed 8 weeks post-stroke onset. The lesion is confined to the territory of the left middle cerebral artery, involving the inferior parietal lobule, insula, external capsule, lentiform, and caudate nuclei, internal capsule and the periventricular white matter.

45 min. Each session consisted of a warm-up task alternation block (20 trials) followed by five experimental blocks (80 trials each). The first four blocks involved task alternation while the fifth block involved a single-task (SIZE in Session 1 and SHAPE in Session 2). The patient was informed about the transition from task alternation blocks to a single-task block verbally by the experimenter. Namely, she was told that from now on she is required to perform only one task (either the SIZE or the SHAPE, in each session), and that the cues would not alternate. The patient was asked to respond as quickly and as accurately as possible and was also reminded of the task instructions after each block. At the end of the session, she was asked to explain the task instructions, using gestures if needed, which she did successfully.

All the control groups responded with their non-dominant hand as did AF. Their conditions resembled AF's first session.

3. Results and discussion

In the analyses of AF's results, the unit of observation was a single trial, while for the control groups we used cell means as usual. Because most of the reaction time (RT) analyses were not conducted on the first 40 trials of Session 1 (see below) and because all the remaining RTs fell between 100 and 5000 ms, we analyzed all the accurate trials beyond trial 40 for RT. We adopted an $\alpha = .05$ in all the comparisons. The results are presented as follows. First, we show evidence that AF understood the instructions and switched tasks reasonably well in the first 40 trials of Session 1. Second, we show evidence that in all the subsequent task-alternation trials AF performed only the SIZE task instead of switching tasks. Finally, we present the behavioral markers of her intention to switch tasks.

3.1. Successful switching in the first 40 trials

It is essential to demonstrate that AF understood the experimental instructions and the verbal task-cues. This was evident in two ways. First, AF was able to correctly answer questions with gestures regarding the stimulus–response key mapping for each task at the end of each session. Second, she was able to switch tasks reasonably successfully in the first 40 trials of Session 1 (the 20 warm-up trials and the first 20 trials of Block 1). Successful switching was inferred from the pattern of errors, depending on how responses were mapped to the response-keys in the two tasks (see Fig. 3).

As a consequence of the stimulus–response mapping described in Fig. 3, congruent trials are not informative in terms of which task AF committed. On the other hand, in the incongruent condition, a correct response was most likely achieved by executing the correct task rule. For example, assume that the tasks are performed with 100% accuracy but that only one task is performed. This would lead to 100% accuracy in the congruent condition and in the incongruent condition when the task is required. However, when the alternative task is required, this would lead to zero accuracy in the incongruent condition. Following this line of reasoning, we present in Table 1 the proportion of correct responses of AF as well as of the matched control group. The most critical data pertain to the incongruent SHAPE responses. For AF, the majority of these responses were correct in the first 40 trials (6 out of 9), whereas there was

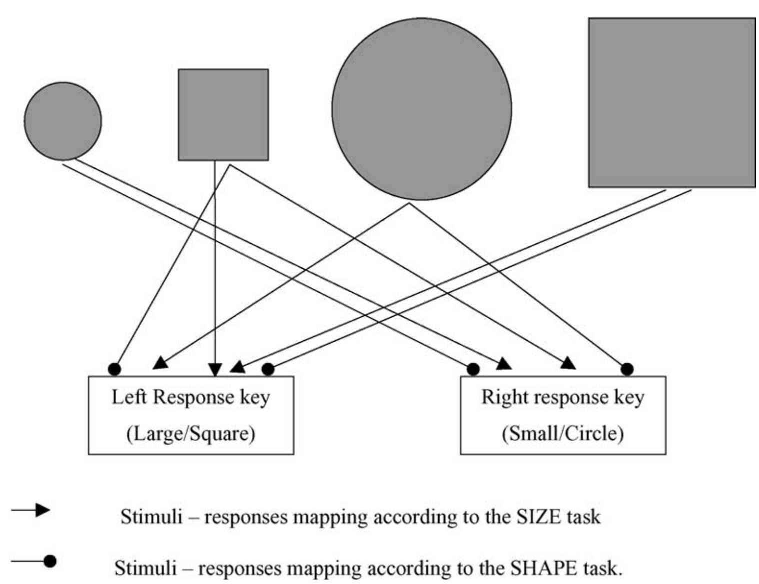

Fig. 3. Stimulus–response mapping. This mapping produces conditions in which two task-rules point to the same response key as the correct response. This was true for the *small circle*, because both SMALL and CIRCLE were mapped to the right response key. Similarly, both responses to the *large square* were mapped to the left response key, because the attributes LARGE and SQUARE were both mapped to that key. Trials involving these two targets represent the *congruent* condition. By contrast, trials involving the two remaining targets represent the *incongruent* condition because the different dimensions of the target were mapped to opposite response keys.

Table 1
Proportion of correct responses according to congruency, task and trial-position for AF and the matched control group

		Trials 1–40—Session1		Remaining trials—Session 1		Session 2	
		SHAPE	SIZE	SHAPE	SIZE	SHAPE	SIZE
AF	Congruent	.91	.66[a]	1.00	.98	1.00	1.00
	Incongruent	.67	.80[a]	.01[a]	1.00	.00	1.00
Matched	Congruent	.96 (.07)	.98 (.04)	.98 (.03)	.99 (.01)		
Control group[b]		.84–1.00	.90–1.00	.92–1.00	.97–1.00		
	Incongruent	.86 (.14)	.95 (.07)	.94 (.04)	.98 (.03)		
		.63–1.00	.84–1.00	.88–.98	.95–1.00		

[a] Cases in which AF was outside the normal control-group range.
[b] Proportion of correct responses for the control group are reported in terms of mean (S.D.) and range (below).

only 1 correct response out of 74 in the remainder of Session 1 (a significant difference by Fisher's exact test).

The results in Table 1 also indicate that AF switched tasks in the first 40 trials of Session 1 and no relative difficulty was observed in performing the SHAPE task. In fact, her level of accuracy in the first 40 trials in congruent and incongruent trials of the SHAPE task, was inside the normal range of the matched control group. However, surprisingly, her performance in the congruent SIZE trials (the task she continued to perform afterwards) was 6.00 matched control-SDs away from the worst matched control performance. For incongruent SIZE trials, her performance was poorer than that of the worst control subject, but by only .57 matched control SDs.

3.2. Evidence that AF performed only the SIZE task after trial 40

In all the following analyses, we excluded the first 40 trials in Session 1 in which AF switched tasks, as we will show below. In the remaining trials of Session 1, accuracy was almost perfect in the SIZE task: .98, 1.00, for congruent, and incongruent trials, respectively (ns., by Fisher's exact test). A different pattern was found for the SHAPE task, in which accuracy was perfect in congruent trials but almost zero (.01) in incongruent trials (a significant difference by Fisher's exact test). AF's SHAPE task performance in the last incongruent trials of Session 1 was 21.75 matched-control SDs below that of the worst performing matched control subject. This pattern of poor performance was replicated in Session 2. Our informal observation that AF was performing only the SIZE task was bolstered by multinomial modeling (Meiran & Daichman, in press; Riefer & Bachelder, 1988), see Appendix A.

3.3. Relative task difficulty

Accuracy and RT comparisons of the two single-task conditions indicate that the SHAPE and the SIZE tasks were of similar difficulty for AF. RT for the SIZE task was 1111 ms and the proportion of accurate responses was 1.00, compared to 1077 ms, and .98 for the SHAPE task. Neither the RT difference nor the difference in proportion of accurate responses approached significance. This comparison indicates that AF could perform that SHAPE task relatively well when it was presented alone, and that the SIZE task was not dominant due to its difficulty per se.

3.4. Behavioral markers of intentionality

The results from the matched control group, who switched between tasks, indicated the usual effects of mixing cost, switching cost, congruency effect and preparation effect, similar to the ones reported by Meiran, Gotler, and Perlman (2001).

Fig. 4a and b depict the mean RT and the mean proportion of correct responses, respectively, according to Block and Group. In the case of single-task blocks, we present the results separately for each of the 10 mini-blocks, eight trials each.

3.5. Transition to single-task conditions

First we will refer to AF's Session 1. As can be seen in Fig. 4a and Table 2, the transition from the task-alternation blocks to the single-task block was accompanied by a substantial and significant increase in RT. These result is very surprising because AF performed the SIZE task in

Table 2
RT rise (in ms) in the transition to single-task block

	Last task alternation block	First single-task mini-block	Rise (proportion)[a]	*t* (d.f.)[b]
AF Session 1	1290	1513	223 (.20)	$t(569) = 1.91$
"Ignore" group	573	633	60 (.10)	$t(17) = 1.08$, ns
"Attended color" group	589	727	138 (.25)	$t(17) = 2.33$
Matched control group	1409	1441	32 (.03)	$t(7) = .20$, ns

[a] Proportion of RT rise was estimated by fractionating the rise in the total reaction time in the single-task block after excluding the first mini-block.
[b] All analyses were based on planned comparisons.

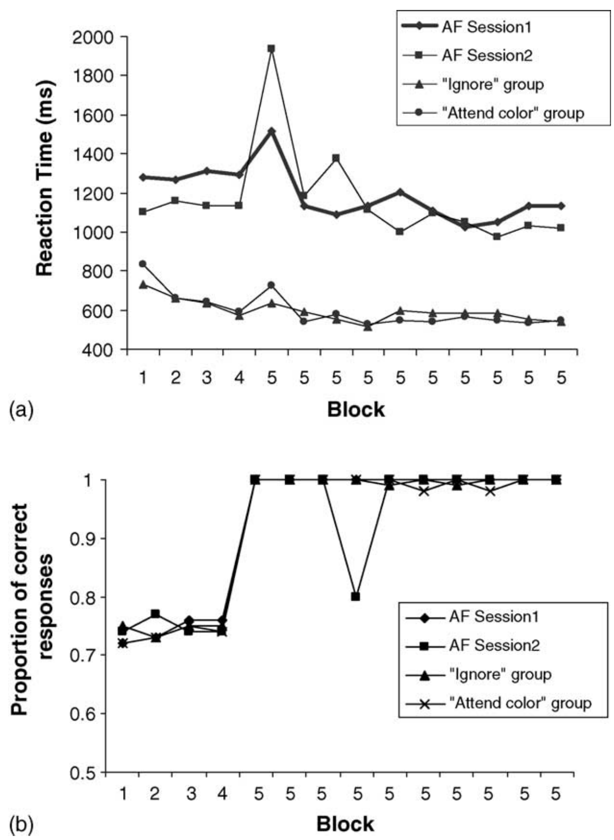

Fig. 4. (a) Mean RT (ms) according to Block and Group of subjects. For all groups, Blocks 1–4 refer to task alternation blocks each containing 80 trials. Block 5 is divided to 10 mini-blocks, each of which contains runs of eight trials. The first mini-block marks the transition from task alternation conditions to the single-task condition. The single-task block of AF's Session 1, the "Ignore" and the "Attend color" groups, involved the SIZE task, while in AF's Session 2 it involved the SHAPE task. (b) Mean proportion of correct responses according to Block and Group of subjects. *Note:* Since all groups eventually performed only one task (the SIZE task) in the task alternation blocks, their overall proportion of correct responses was nearly .75. This resulted from a nearly perfect performance in the congruent trials and a .5 proportion in the incongruent trials. Also, in the single-task condition performance was nearly perfect for both types of trials.

both blocks. A similar RT rise took place also in Session 2, but this rise could be attributed to the task change itself.

This increase RT in Session 1 is assumed to be due to a change in the goal-state, from switching between tasks to performing a single-task. A similar increase was observed among the "Attend color" group but was neither found among the "Ignore" group nor among the matched controls. The proportional RT rise was similar for AF's Session 1 (.20) and "Attend color" (.25) but was smaller among the "Ignore" group (.10) and the matched controls (.03). These result suggests that the rise is found when one previously attended to the cues but did not switch tasks. Therefore, we suggest that RT rise in the transition to single-task condition accounts for a change in the task goal, specifically a change from "attending to the cue" to "disregarding the cue".

Allport and Wylie (2000, Experiment 4, cf. Gopher, Armoni, & Greenshpan, 2000) showed a similarly substantial increase in RT in the beginning of a run of trials, even when there was no task-switch (termed as "restart cost"—although demonstrated on the single first trial of the run). In order to ensure that the RT rise in the case of AF does not reflect a variant of that phenomenon, we looked for comparable restart costs in the alternating blocks. This was done by comparing the first eight trials in the alternating Blocks 2–4 with the next eight trials in these same blocks. The analysis was conducted on eight trial mini-blocks so as to be comparable to the analysis of transition to the single-task block. The results indicated no evidence for "restart cost". Mean RT was 1261 ms for the first mini-block in Blocks 1–4, compared to 1384 ms in the next mini-block, and 1269 ms in the last 64 trials of the block, in the same blocks. This shows that for AF, there was no significant increase in RT at the beginning of each task alternation block in Session 1.

3.6. Task alternation cost

Although AF performed the SIZE task throughout Session 1, when it was performed in the single-task block, RT was faster as compared to the task alternation blocks (Table 3). This RT difference is known as the "task alternation cost" (Fagot, 1994). First, we tested whether this trend of RT reduction between the two experimental conditions results from practice. Because we had only four task alternation RT means, we could not fit a power function, which is known to fit learning curves, but fitted a linear function instead. In Session 1, AF showed no learning effect in the task alternation condition and actually demonstrated an average RT *gain* of 7 ms per block. We used the best fit linear function to predict the RT in the single-task condition (after excluding the first mini block). The predicted mean was 1304 ms, which contrasts with the significantly quicker actual mean of 1111 ms, $t(8) = 10.37$. Therefore, we tested the RT difference between the task alternation blocks and the single-task block. We found a significant task alternation cost in Session 1, $t(569) = 4.12$.

AF also did not show any learning effect in the task alternation condition of Session 2, with an average RT gain per block of 6 ms. Because AF performed a different task in the single-task condition of Session 2 (the SHAPE task), we could only compare her performance in the task alternation blocks of Session 2 to the single-task block of Session 1. Following Table 3, no significant alternation cost effect was found in Session 2 according to this criterion.

We conducted a similar analysis on the results of the "Ignore" and the "Attend color" groups. In the "Ignore" group, we observed a learning effect in the task alternation condition of 75 ms per block, and therefore the predicted RT in the single-task condition due to practice was 495 ms, *less than* the actual RT, 546 ms. Similarly, the "Attend color" group showed a learning effect of 49 ms per block, leading to a predicted single-task RT of 527 ms, less than the actual value of 566 ms. The fact that the prediction fell below the actual

Table 3
RT differences (in ms) between the task alternation blocks and the single-task block ("task alternation cost")

	Mean RT in the task alternation blocks	Mean RT in the single-task block[a]	Predicted mean RT in the single-task block[b]	t(d.f.)[c]
AF Session 1	1287	1111	1305	$t(569) = 4.12$
AF Session 2[d]	1130	1111	1144	$t(569) = .43$
"Ignore" group	649	566	527	[e]
"Color" group	682	545	495	[e]

[a] Mean RT in the single-task block after excluding the first mini-block.
[b] Predicted RT headed just due to practice.
[c] Analysis of the RT difference between mean RT in the task alternation blocks and the mean RT in the single-task block. This analysis was based on planned comparisons.
[d] Since AF performed the SHAPE task in the single-task block of Session 2, we could only compare her performance in the task alternation block of Session 2 to the single-task block of Session 1.
[e] Differences between the mean RT and the predicted mean RT in the single-task block were negative and therefore there was no reason to test the significance of the task alternation cost.

Table 4
RT differences (in ms) between incongruent and congruent trails ("task-congruency effect")

	Mean RT in incongruent trials	Mean RT in congruent trials	Effect size	t(d.f.)[a]
AF Session 1—task alternation blocks	1341	1243	97	$t(569) = 2.10$
AF Session 1—single-task block	1115	1188	−73	$t(569) = 1.05$, ns
AF Session 2—task alternation blocks	1141	1119	22	$t(569) = .47$, ns
AF Session 2—single-task block	1260	1076	184	$t(569) = 2.88$
"Ignore" group—task alternation blocks	662	642	20	$t(17) = 1.11$, ns
"Ignore" group—single-task block	574	569	5	$t(17) = .76$, ns
"Attend color" group—task alternation blocks	691	669	22	$t(17) = 1.76$
"Attend color" group—single-task block	584	544	40	$t(17) = 3.40$

[a] All analyses were based on planned comparisons.

value in both cases could be attributed to the use of a linear instead of power function. In any case, the present analyses indicate no task alternation cost for the "Ignore" and "Attend color" groups.

In order to ensure that task alternation cost was not restricted to a small subclass of trials, we analyzed the first, second and third quartiles (Q1–Q3) of the RT distribution. The task alternation cost was 47, 162, and 283 ms in Q1–Q3, respectively. Thus, even though AF did not switch tasks, she demonstrated alternation cost that was evident in the entire RT distribution.

These results suggest that the task alternation cost demonstrated by AF in Session 1 does not result from practice, the change from varying cues to constant cues (the "Ignore" group and AF's Session 2) or some superficial processing of the task-cues (the "Attend color" group). Rather it seems to reflect her partially activated intention to switch tasks.

Moreover, we tested whether the task alternation cost found in AF's Session 1 resulted from the inconsistency of the SHAPE cues with SIZE task goal (a Stroop like effect). We tested the task alternation cost separately for the instructed SHAPE trials (1220 ms) and the instructed SIZE trials (1294 ms) in Session 1. Both values differed significantly from the mean = 1111 ms in the single-task block of Session 1, $t(141) = 2.08$, $t(217) = 3.51$, respectively. These results rule out this alternative explanation as well.

3.7. Congruency effect

The task-congruency effect (incongruent RT > congruent RT) reflects the fact that the competing response mapping was active (Table 4).[1]

As seen in Table 4, AF showed a significant congruency effect in the task alternation condition, indicating that she held both task sets active in spite of performing only the SIZE task. However, when she performed the SIZE task as a single-task block, at the end of Session 1, there was a non-significant *reversed* congruency effect (−73 ms). In contrast, in Session 2 she showed a much smaller and non-significant congruency effect (similar to the one observed in the "Ignore" group). The positive and significant congruency effect shown by AF in the single-task condition of Session 2, in which she performed the SHAPE task can be explained by AF's strong tendency to perform the competing SIZE task, and possibly to some stimulus-task binding (Allport & Wylie, 2000; Waszak, Hommel, & Allport, 2003), which caused the target stimuli to retrieve the wrong task set.

[1] The task-congruency effect is quite different from the well known stroop effect because the former is based on a newly instructed task rule, whereas the latter results from pre-experimental tendencies. In the literature, this difference refers to short-term versus long-term stimulus–response links (e.g, Tagliabue, Zorzi, Umilta, & Bassignani, 2000; cf. Meiran, in press, in regard to task switching).

Interestingly, the "Ignore" group, who, like AF, performed only the SIZE task in the task alternation blocks, showed a small and insignificant congruency effect. This serves as an indication that, unlike AF, they did not keep the intention to perform the SHAPE task. However, the "Attend color" group showed a congruency effect in the task alternation blocks which reached one-sided significance, $t(17) = 1.76$. This accords with the instructions given to them to maintain some readiness to perform the SHAPE task.

We have no account for the congruency effect found in this group when they performed the same task in the single-task block.

One could argue that the congruency effect in the task alternation blocks resulted from proactive interference from the previously executed task sets in the first 40 trials of Session 1 (e.g., Allport, Styles, & Hsieh's, 1994, "task set inertia" hypothesis). If this were true, one would predict congruency effects to diminish in the course of the task alternation blocks. Although the pattern was somewhat unclear due to the small number of trials analyzed, AF's congruency effect did not show any trend for gradual reduction. It was 96, −68, 205, and 137 ms in Blocks 1–4, respectively. In contrast, a declining trend was observed in the "Ignore" group (34, 32, 0, and −4 ms in the Blocks 1–4, respectively) as well as in the "Attend color" group (40, 42, 30, and −2 ms, in Blocks 1–4, respectively).

4. Summary and conclusions

We argue that the best account of the results is that AF *partially* intended to switch between tasks in the task-alternation blocks of Session 1 but not in Session 2. First, in both sessions AF performed only the SIZE task, but in Session 1 she switched tasks in the first 40 trials, while in Session 2 she did not switch tasks at all. Second, in Session 1 she demonstrated task alternation cost, while in Session 2 this effect was absent. Third, in Session 1 she demonstrated a task congruency effect in the task alternation blocks, while in Session 2 this effect was absent. Last, in Session 1 transition to a single-task block was accompanied by increasing RT, likely due to the change in the global context of the experiment from a task alternation condition to a single-task condition. We suggest that the task alternation cost, the congruency effect, and the initial increase in RT in the transition to single-task condition indicate, behaviorally, AF's partially activated intention to switch tasks. This intention was present in Session 1 but was absent in Session 2.

Taken together the results seem to indicate that intention can be activated in a gradual manner rather than in an all-or-none fashion. From this perspective, the matched controls had the strongest intention to switch tasks, as seen in their successful switching. As a result of having both task sets active, they have showed all the usual effects of switching cost, mixing cost and task-congruency effect. However, they did not show the RT rise in the transition to a single-task block. On the other extreme, the "Ignore" group had no intention to switch tasks at all. As a result, they did not show any of the behavioral markers of intentionality. AF and the "Attend color" group were in between these extremes. The "Attend color" group processed the task-cues superficially, to detect a color mismatch, but did not intend to switch tasks in any given trial. Therefore, they did not show the task alternation cost, but showed a congruency effect. AF showed a more strongly activated intention as evident in her relatively large congruency effect and task alternation cost. The RT rise in the transition to a single-task condition was demonstrated by AF as well as by the "Attend color" group. The common denominator of both was the attention to the task-cues, which is a necessary (but apparently, insufficient) part of the intention to switch tasks.

Although the "Attend color" group showed a significant task-congruency effect, the size of the effect was only 28% of the congruency effect demonstrated by 96 students who were tested on the same experiment as AF, and switched between task (Yehene & Meiran, submitted for publication). In contrast, AF's congruency effect was 48% of that observed among the matched control group. These result, too, supports our conclusion that the intention to switch tasks was stronger for AF than for the "Attend color" group.

The notion that the present results reflect AF's ineffective *intention* to switch tasks can be objected by an alternative explanation (suggested by an anonymous reviewer) according to which AF strategically *abandoned the intention* to switch. To elaborate, this explanation assumes that since AF was struggling to switch tasks, at some point (i.e., after 40 trials) she had abandoned switching altogether (namely elected not to switch). By doing so, she was able to sustain the accuracy level she achieved in the first 40 trials (.75). In light of this explanation, the congruency effect demonstrated by AF in the task alternation condition, originates from interfering stimulus-task associations, that were established in the short period in which she performed both tasks (the first 40 trials). In addition, the alternation cost can be related to interference caused by the presence of SHAPE task-cues in the task alternation condition, relative to the single-task condition. Finally, the RT rise in the beginning of the single-task condition is interpreted as reflecting a change in a strategy; a change from "ignoring the experimental instruction" to "following the instructions".

A definite resolution between the two explanations (the "strategy" versus the "ineffective intention" explanation) probably cannot be accomplished without further experiments. However, we believe that the "strategy" explanation presented above is less parsimonious than the one we provide. First, the "strategy" explanation cannot account for the abrupt disappearance of the congruency effect in the single-task condition of Session 1, an effect that was strong and consistent throughout the task alternation condition. If this effect indeed resulted from the interference of the competing stimulus-task associations, one would expect this interference to appear in the single-task condition as well (or at least to gradually decrease). Second, we ruled out the possibility that the task alternation cost results from the cue mixing and from the presence of small sub-class of trials. Moreover, if this account was valid, one would expect alternation cost to appear both in AF's Session 2 and in the "Ignore" group (which was strategically asked to ignore the SHAPE task), something that did not happen. As for the RT rise in the beginning of the single-task condition, we think that the two explanations deal with this phenomenon similarly, by arguing for a general change in AF's coping with the two experimental conditions, although for different reasons.

Thus, given AF's partially activated intention to switch, it is interesting why AF did not switch tasks, eventually. Due to her speech disorder, she could not explain in words what her intentions were or how she performed the task. However, it seems that multitasking caused her effort. This was evident in two ways. First, RT in the first 40 trials in which she switched task was significantly higher (1991 ms) than her RT in the first block when she started to perform only the SIZE task (1281 ms), $t(290) = 6.18$. Second, when she performed the tasks in isolation, her accuracy was almost perfect. It might be the case that since switching was too demanding for her, it resulted in an especially pronounced general fatigue or resource depletion, that eventually led her to abandon actual switching. However, the RT pattern in both sessions (see Fig. 4a), appears quite robust and does not indicate a pattern of substantial slowing, which is expected with fatigue.

We attribute her deficit to the depletion of a specific resource. According to Rubinstein, Meyer, and Evans (2001), two cognitive control processes take place during switching, "goal setting" and "rule implementation". Recently, Meiran, Friedman, and Yehene (2004) have demonstrated a dissociation between these two processes in patients with Parkinson's Disease (PD). In this study, half of the PD patients exhibited performance that approximated guessing in incongruent trials (when a correct response depended on correct task identification). On the contrary, their performance was nearly perfect in congruent trials (when a correct response could be made by applying the wrong task rule) as well as in single-task condition (when only one task rule is required). Nevertheless, these patients were able to benefit from long preparation time interval to reduce their switching cost, similar to the PD patients, who did not exhibit such an error pattern. This study suggests that some PD patients exhibit a selective goal setting deficit without exhibiting a deficit in task rule implementation. Specifically, the impaired patients were able to prepare normally to the upcoming task, even when this preparation was towards the wrong task.

Since AF's lesion also involved the basal ganglia (BG), we suggest that her deficit may be related to goal setting processes. However, since AF performed only one task, it was not possible to observe preparation related reduction in switching cost, and therefore a deficit in rule implementation cannot be ruled out. In addition, we also tested a group of patients with focal BG lesions who, like AF, did not switch tasks. However, none of them showed the behavioral markers of the intention to switch tasks. In fact, their performance resembled that of the "Ignore" group and to AF's performance in Session 2 (Yehene, Meiran, & Soroker, submitted for publication). We would argue that BG lesions lead to goal setting deficit, but the difference between AF and the remaining patients with BG lesions lies in the partial intention to attempt task switching.

It is still an open question why AF continued to perform only the SIZE task in Session 2 after 5 days of rest. Given AF's goal setting deficit, switching was effortful to her in general, even after 5 days of rest. However, the loss of partial intention to switch tasks still needs to be resolved. A possible explanation might be in terms of motivational differences between Sessions 1 and 2. Due to her utter failure to switch tasks in Session 1, she might have completely abandoned the effort to switch tasks in Session 2. Moreover, since AF performed the SIZE task throughout Session 1, she was well trained in performing this task. This might explain her initial bias to perform the SIZE task in the task alternation condition of Session 2, and to abandon the SHAPE task altogether. The latter argument is somewhat similar to the aforementioned "strategy" explanation we discussed, although in regards to Session 1.

Another potential general explanation for the current results may be based on Zelazo and Frye's (1996) Cognitive Complexity and Control (CCC) model. According to CCC, it is the failure to represent a high-order rule, which combines the two tasks, that leads to selecting one rule only. Because AF succeeded in switching in the first 40 trials of Session 1, we think that the CCC account does not apply in the present case. We prefer another potential explanation. Recent models of working memory (WM) draw a distinction between the activated part of Long Term Memory (LTM) and a more central component, the Focus of Attention (FOA; Cowan, 1995; Oberauer, 2001, 2002). Oberauer's experiments are especially relevant here. In these experiments, participants were instructed to memorize two lists of words. Afterwards, one list was cued, and a word was presented. The task was to decide whether the word was part of the cued list or not. Oberauer found that increasing the pre-warning interval led participants to search only the cued list, indicating their focusing of attention. However, there was an intrusion effect (difficulty rejecting items from the irrelevant list) which indicated that the elements in the irrelevant set were activated above baseline in LTM. This interference effect was robust even in the longest preparation intervals. We suggest that the intrusion effect observed by Oberauer is analogous to the congruency effect and the task alternation cost, which reflect the activated yet irrelevant task set. Based on this analogy, switching means to remove the no-longer-relevant task set from the FOA and bring the relevant task set into this focus. In these terms, AF held the two task sets in the activated LTM aspect of her WM, but focused on the SIZE task only.

The present results also bare relevance to theories explaining the task alternation cost. Fagot (1994) fractionated the task alternation cost into "switching cost" (the difference in performance between switch and non-switch trials, both from the mixed tasks condition) and "mixing cost" (the difference between mixed tasks and single-task performance). The fact that AF did not demonstrate a switching cost is not surprising. Apparently, for switching cost to be observed, participants must execute the correct task in the preceding trial (Schuch & Koch, 2003). Accordingly, the only group in this study who demonstrated switching cost was the matched controls. Based on Fagot's scheme, AF showed mixing cost but not switching cost.

One explanation of the mixing cost is based on the notion of consistent practice. This theory holds that the mixed tasks condition does not allow for practice because of the inconsistency, but the single-task condition allows for practice to accumulate over trials (Meiran, 2000). AF's results show that this cannot be the sole reason for the task alternation cost because AF, who did not switch tasks, showed such cost. Other explanations emphasize the role of strategies. Following Los (1996), the strategic view holds that participants are less well prepared in mixed blocks than in pure blocks due to greater task uncertainty. This uncertainty explanation also does not hold in AF's case, because only one task was performed. Rogers and Monsell (1995) argued that the task alternation and the single-task conditions might differ in effort and arousal due to differential complexity. Although we cannot rule out arousal and effort, we can rule out complexity since the complexity of the task alternation and the single-task conditions were the same for AF, as she did not switch tasks. Also, the difference between these two experimental conditions in the need to ignore the SHPAE task-cues in the task alternation condition has already been ruled out. A possible explanation is based on Los's (1996) suggestion that the mental system is more heavily loaded in mixed tasks blocks than in pure blocks. In the case of AF, the fact that she showed congruency effect suggests that she held two task-sets in mind when performing in the task alternation blocks and therefore had a higher mental load. Another possible account for the results is in terms of differential response criteria or intermediate strategies (e.g., Los, 1996), although it remains unclear why these would increase rather than decrease the task-congruency effect.

Another reason why the present findings are important is the fact that the decomposition of the task alternation cost into switching cost and mixing cost (e.g., Fagot, 1994; Meiran, Chorev, & Sapir, 2000) is based on two *dependent* contrasts: switch versus non-switch and non-switch versus single-task. This point can be easily understood in the following example: for a case in which switch RT and single-task RT remain constant, an increase in non-switch RT would decrease switching cost and increase mixing cost to the same degree. Thus, statistical considerations as well as practical complications might lead one to suspect whether this decomposition is truly justified.

AF's case supports the decomposition because she did not exhibit "switching cost"[2] (mean RT was 1200 and 1198 ms for switch and non-switch, respectively, ns.). Nevertheless, she exhibited significant mixing cost. The virtually zero "switching cost" shows that the effect is not (only) due to cue repetition, in contrast to Logan and Bundesen's (2003) recent claims.

Acknowledgements

This study was approved by the appropriate ethics committee and has therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. The subjects gave their informed consent prior to their inclusion in the study.

Appendix A

According to the model presented below, task switching is hierarchical. The participant first decided which task to execute and only then chose which response to commit. The assumption concerning such hierarchical choice was supported by Biederman (1972), is shared by several more recent approaches (Gilbert & Shallice, 2002), and is supported by the reduction in switching cost by preparation (de Jong, 1995; Rogers & Monsell, 1995) as well as by the results of normal subjects (Meiran & Daichman, in press). Fig. 5 shows a schematic illustration of the model.

The model yielded an estimate of three parameters: t, the probability to select the correct task, C, the probability for correct response choice, given that the correct task was chosen, and W, the probability of choosing the correct response, given that the incorrect task was chosen. Each of these parameters was estimated for SIZE (a) and SHAPE (b) tasks, separately. Also, responses in this experiment were defined as follows:

E1 – correct response in the congruent condition – SIZE task
E2 – incorrect response in the congruent condition – SIZE task
F1 – correct response in the incongruent condition – SIZE task
F2 – incorrect response in the incongruent condition – SIZE task
G1 – correct response in the congruent condition – SHAPE task
G2 – incorrect response in the congruent condition – SHAPE task
H1 – correct response in the incongruent condition – SHAPE task
H2 – incorrect response in the incongruent condition – SHAPE task

Table A.1 shows the maximum likelihood estimation of the parameters for both tasks (to enable estimation, we replaced the few 0's by .0001 and the few 1's by .999).

The results indicated an acceptable degree of model fit with insignificant deviation of the data from the model, $G^2(\text{d.f.} = 2) = 1.77$, ns. We interpret the estimated parameter values as followed: while performing the SIZE task, AF

[2] We used the term 'switching cost' here not in it's traditional manner since AF did not actually switch tasks. Rather, we refer here to the lack of RT difference between trials in which she was requested to switch task and trials in which she was requested to repeat the same task.

Table A.1
Maximum likelihood estimates of the model parameters for the SIZE task and the SHAPE task [G^2(d.f. = 2) = 1.77, p = .41]

Parameter	Definition	Maximum likelihood estimate
ta	The probability of choosing the correct task—SIZE	.99
tb	The probability of choosing the correct task—SHAPE	.006
Ca	The conditional probability of choosing the correct response, given it was also the correct task—SIZE	.996
Cb	The conditional probability of choosing the correct response, given it was also the correct task—SHAPE	.99
Wa	The conditioned probability of choosing the correct response, given it was the wrong task—SIZE	.65
Wb	The conditioned probability of choosing the correct response, given it is the wrong task—SHAPE	.99

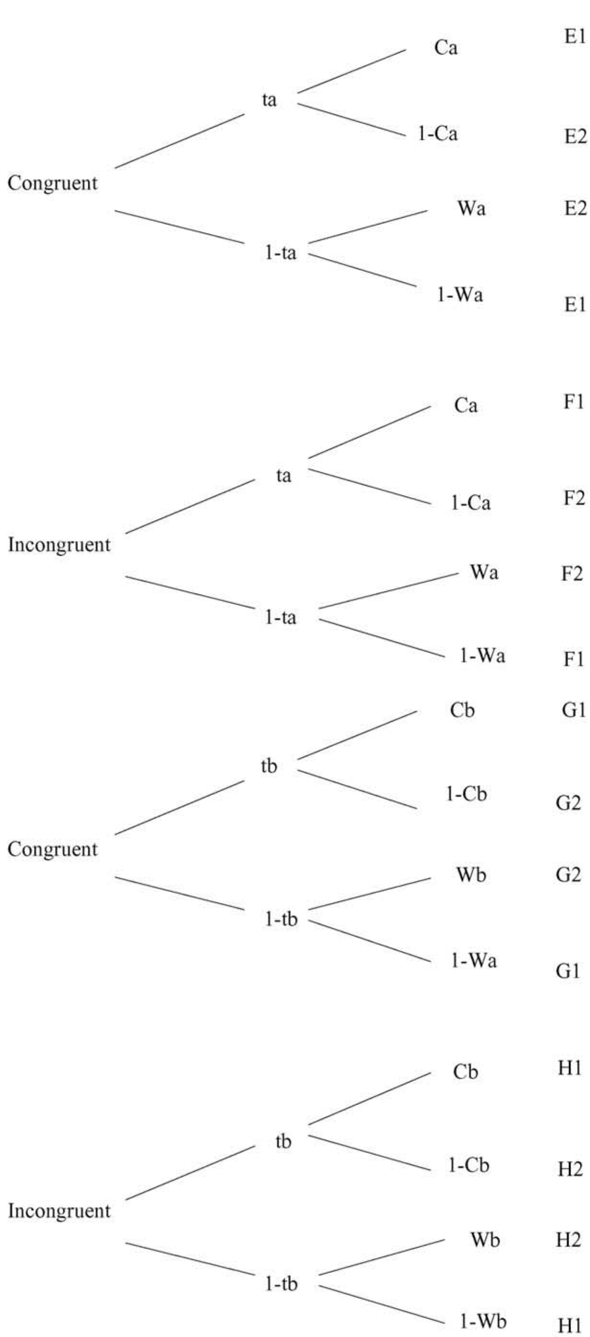

Fig. 5. Schematic illustration of the hierarchical model.

almost always chose the correct task. When she chose the correct task, she always responded correctly. However, when she chose the wrong task (SHAPE instead of SIZE), there was a low probability of getting the correct response (.65). On the other hand, for the SHAPE task, AF almost never (probability of .006) chose to perform the correct task (SHAPE); thus, she almost always performed the SIZE task instead. In the rare cases in which she correctly chose the SHAPE task, there was a high probability of her getting the correct response (.99). However, when she chose the wrong task, SIZE, her performance on this task was perfect.

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