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Environmental Adaptations Improve Everyday Action Performance in Alzheimer's Disease: Empirical Support From Performance-Based Assessment

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Neuropsychologists often recommend that patients with dementia and their caregivers use environmental adaptations to improve everyday functioning. Although these recommendations are intuitive (e.g., reduce clutter), most have never been experimentally tested. This study examined whether and how environmental adaptations improved everyday action in Alzheimer's disease (AD). Forty-six outpatients completed the Naturalistic Action Test (NAT; M. F. Schwartz, L. J. Buxbaum, M. Ferraro, T. Veramonti, & M. Segal, 2003), which requires completion of 3 everyday tasks. The NAT was administered under 2 conditions: standard and user centered. The standard NAT followed the procedures of the manual; object placement was standardized, but objects were not meaningfully arranged on the tabletop. In the user-centered NAT, objects were arranged in the order needed in the task, and a visual cue to monitor performance was placed on the table. These conditions were counterbalanced across participants. The user-centered condition improved performance on all NAT items and reduced commission and omission error rates. However, post hoc examination of commission error types showed improvement of substitution and off-task errors but no difference in anticipation and perseveration errors. Thus, environmental adaptations improved everyday performance in AD by facilitating task accomplishment, object selection, and task-congruent actions.

Keywords: naturalistic action, activities of daily living, instrumental activities of daily living, rehabilitation, remediation

Everyday activities are familiar tasks that require multiple cognitive and motor processes, such as serial ordering of task steps, object selection, tool use, and so on, to achieve practical goals (preparing coffee, grooming, etc.). Everyday tasks are familiar and routinely performed with subjective ease; however, even healthy individuals are prone to intermittent errors on these tasks, and error rates increase when individuals are tired or distracted (Giovannetti, Schwartz, & Buxbaum, in press; Reason, 1990). Among individuals with brain damage or disease, errors are more frequent and may preclude achievement of the task goal (Buxbaum, Schwartz, & Montgomery, 1998; Humphreys & Forde, 1998; Schwartz et al., 1998, 1999). Everyday action errors are a serious concern in dementia (Giovannetti, Libon, Buxbaum, & Schwartz, 2002). In fact, everyday action impairment is one of the diagnostic criteria of Alzheimer's disease (AD; American Psychiatric Association, 2000) and is associated with numerous serious consequences, including depression, institutionalization, and death (Knopman, Kitto, Deinard, & Heiring, 1988; Noale, Maggi, & Minicuci, 2003). In an effort to prevent these dire consequences, neuropsychologists commonly recommend that dementia patients and their caregivers use environmental adaptations to facilitate everyday functioning. However, there has been very little empirical research on strategies to improve everyday action performance. Thus, the primary goal of this article was to test the efficacy of environmental adaptations for improving everyday action in AD.

To date, research on everyday action interventions in dementia has shown that extensive training and repetition of everyday activities improves performance on the trained tasks (e.g., *procedural memory stimulation*; Avila et al., 2004; Farina et al., 2002; Josephsson et al., 1993; Josephsson, Backman, Borell, Nygard, & Bernspang, 1995; Zanetti et al., 1997, 2001). A wide variety of environmental adaptations have been suggested for dementia patients (e.g., cue cards, sparse workspace), but few studies have directly assessed their efficacy without extensive patient training. One exception is a study by Gitlin, Corcoran, Winter, Boyce, and Hauk (2001) that explored the effect of individualized home-based environmental adaptations among 171 dementia participants following caregiver training. Results showed improved functioning

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and reduced caregiver burden; however, data were obtained from caregiver ratings, which are prone to bias. Moreover, the ratings did not gather information regarding how the adaptations actually had improved functioning. Others have used observational data and/or performance-based measures to assess environmental adaptations in single cases, but analyses have been descriptive and qualitative (Adam, van der Linden, Jullerat, & Salmon, 2000; Corcoran & Gitlin, 1992).

Our study used the Naturalistic Action Test (NAT; Schwartz, Buxbaum, Ferraro, Veramonti, & Segal, 2003), a performance-based measure of everyday action, to assess the efficacy of environmental adaptations. The NAT was developed for use with inpatient rehabilitation populations (i.e., brain injury and stroke), and it has sound psychometric properties (Schwartz et al., 2003; Schwartz, Segal, Veramonti, Ferraro, & Buxbaum, 2002). NAT scores reflect overall impairment, task accomplishment, total errors, and specific error types. A previous study of 51 participants with dementia demonstrated significant correlations between NAT variables and caregiver reports of activities of daily living (ADL) in the home (Giovannetti, Libon, et al., 2002). Thus, because the NAT (a) is well researched, (b) yields scores that relate to performance in the home, and (c) affords quantification of numerous aspects of performance, it is ideally suited for the rigorous assessment of everyday action impairment. Additionally, because the NAT is administered in the laboratory, it could be easily manipulated to test the effect of environmental interventions using standardized procedures across a large group of participants.

When designing the environmental adaptations used in our study, we turned to recent research on everyday action as well as classic studies in cognitive psychology and human factors. For instance, research on everyday action impairment has shown that the rate and distribution of errors are strongly linked to the task demands and environment (Forde & Humphreys, 2002; Giovannetti, Libon, et al., 2002, Giovannetti, Schmidt, et al., 2006; Hartman, Goldenberg, Daumuller, & Hermsdorfer, 2005; Schwartz et al., 1995, 1998). Thus, we considered the work of Fitts and Seeger (1953), who coined the term *stimulus–response (S-R) compatibility* to describe the degree of congruence between actions and the environment. In situations of high S-R compatibility, the number of competing responses is constrained and the probability for errors is reduced; as a result, action may be performed relatively automatically and with minimal effort. However, when the action and environment are incompatible, performance is more likely to be inefficient, resource demanding, and error prone. We reasoned that increasing S-R compatibility might improve action performance in AD. Although this possibility has been suggested by others (Brawley, 2001; Charness & Holley, 2001), there have been no empirical studies examining the effect of increasing S-R compatibility on everyday action in dementia.

Another tactic for improving everyday functioning is to increase error detection or monitoring. That is, because it is virtually impossible to eliminate all errors in everyday tasks, some investigators have focused on promoting task monitoring and error detection (Levine et al., 2000; Manly, Lewis, Robertson, Watson, & Datta, 2002; Norman, 1990; Selnick & Savage, 2000; Winocur et al., 2000). Indeed, prior studies have demonstrated that dementia patients corrected 79% of detected errors on the NAT (Giovannetti, Libon, & Hart, 2002); this suggests that improving error detection might facilitate error correction and task accomplishment. Unfortunately, most strategies designed to promote self-monitoring require deliberation and supervisory control; therefore, they may not be useful for patients with dementia who suffer from deficits in these executive functions (Cicerone & Tupper, 1991; Cicerone & Wood, 1987; Levine et al., 2000; von Cramon & Mathes von Cramon, 1994; von Cramon, Mathes von Cramon, & Mai, 1991). Recently, however, Manly and colleagues (2002) have described an environmentally supported strategy to promote self-monitoring. They reported that when participants were instructed to stop and consider their performance objectives after the presentation of an auditory alert tone, the participants made fewer errors on a clerical task with the auditory cues than without the cues. Human factors researchers have implemented similar techniques, including indicator lights and dialog boxes (e.g., "Are you sure you want to shut down your computer?"), in an attempt to prevent errors on complex tasks (Norman, 1990). This environmental approach to improving self-monitoring holds promise for even moderately to severely impaired dementia populations.

Along these lines, we modified the NAT to (a) increase the compatibility between the environment and performance and (b) promote task monitoring. In this new *user-centered* NAT, objects used for the same subtask were placed in closer spatial proximity than objects used for different tasks or subtasks. To further facilitate object selection and task sequencing, objects were placed on the tabletop from left to right in the order that they should be used in the task. The user-centered NAT also included a monitoring bell as a cue to promote error detection and correction. Participants were directed to press the bell at the end of the task only after they had checked their work. Of note is that both NAT conditions included the same everyday objects and tasks, and performance was evaluated using identical scoring criteria. The only difference between the NAT conditions was the implementation of environmental adaptations that were designed to make task performance less demanding and promote task monitoring.

In summary, the goal of this study was to examine and characterize the effect of environmental adaptations on everyday action in AD. This entailed a comparison of performance on the NAT (as described in the test manual; hereafter *standard* NAT) versus the novel, user-centered NAT. Comparisons were made on overall performance variables as well as on variables reflecting more specific aspects of performance, including a range of error types and scores on each NAT item. This was done to learn which aspects of everyday action performance (e.g., error rate vs. task accomplishment) benefited most from the environmental adaptations. Last, analyses were performed to elucidate the participant factors associated with the greatest benefit from environmental adaptations.

Method

Participants

Fifty-two participants diagnosed with probable or possible AD (McKhann et al., 1984) were recruited for the study, but 6 participants did not return for the second session. The remaining 46 participants provided sufficient power (.96) to detect a medium effect size (.5) in all primary analyses with alpha set at .05 (Erdfelder, Faul, & Buchner, 1996).

Participants were recruited from an outpatient assessment program that included evaluations by a geriatrician and neuropsychologist, magnetic resonance imaging of the brain, and appropriate laboratory studies. Participants met the following inclusion criteria: (a) Mini Mental Status Exam (MMSE; Folstein, Folstein, & McHugh, 1975) < 26, (b) native English speaker, and (c) no evidence of a focal lesion(s) or cerebrovascular accident(s) on magnetic resonance imaging. Participants were not recruited for the study if they were diagnosed with a comorbid mood disorder or if they had record of prior brain damage or disease, alcohol and/or drug abuse, or major psychiatric disorder. These data were gathered from a review of current and past medical records and an interview with a knowledgeable family member.

Procedures

Participants signed institution review board informed consent forms and were compensated $15.00 per session. Neuropsychological data were obtained as part of a clinical evaluation on the same day that participants were enrolled in the study.

Everyday Action

Participants performed the NAT under two conditions: (a) standard and (b) user centered. In both conditions, the NAT required participants to perform three everyday tasks with little guidance from the examiner: Item 1—prepare toast with butter and jelly and prepare coffee with cream and sugar; Item 2—wrap a gift while distractor objects that are visually and/or semantically similar to target objects (e.g., gardening shears for scissors) are available on the table; and Item 3—pack a lunch box with a sandwich, snack, and a drink and pack a school bag with supplies for school, while several of the necessary objects (e.g., knife, thermos lids) are stored out of view in a drawer with potentially distracting objects. NAT instructions, cuing procedures, and scoring are standardized and described in the test manual. Moreover, as described in the manual, all of the objects needed to perform each task are placed on a U-shaped tabletop at the start of each item (Schwartz et al., 2003).

In the standard condition, the NAT was administered exactly according to the NAT manual, which specifies the placement of each of the objects on the tabletop (Schwartz et al., 2003). Thus, according to the manual, objects for each item were evenly distributed to the right and left of the participant on the U-shaped table, but the objects were not grouped or ordered in any meaningful fashion.

In the user-centered condition, participants performed the same tasks and were presented with the same objects on the same U-shaped table as the standard NAT. However, three environmental adaptations were implemented (see Figure 1). First, objects were arranged on the tabletop from left to right in the order that they should be used in the task. For example, in the toast and coffee task, the bread was placed to the left of the toaster and butter and jelly to the right of the toaster. Second, objects were spatially clustered such that those used for the same step were in closer proximity than those used for different task steps. For instance, the objects used for making toast were grouped together on the tabletop and separated from the objects used for making coffee. Third, to encourage task monitoring, we placed a call bell mounted on a red stand to the right of the last object for each item (hereafter, *monitoring bell*). The words *check your work* were printed on the bell's red stand. The only deviation to this item placement occurred on Item 2, in which the distractor objects were placed to the right of the monitoring bell. Consistent with the NAT manual, the user-centered condition included the same task instructions as the standard (e.g., for Item 2, participants are told the task goal is to wrap a present, to use only the objects that they need to do so, and to repeat the instructions before beginning). Additionally, in the user-centered condition, participants were told that the objects were arranged on the table from left to right in the order that they should be used to help them achieve the task goals. Regarding the monitoring bell, participants were explicitly told that they would reach the monitoring bell (at the far right end of the table) after using the needed objects on the tabletop; they were instructed to ring the bell only after having finished and checked their work.

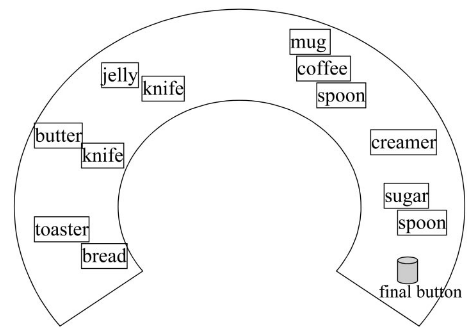

Figure 1. Schematic of Naturalistic Action Test (NAT) U-shaped tabletop showing object placement and task monitoring bell for the user-centered NAT Item 1 (toast and coffee). In the standard NAT, all of the same objects are presented (excluding the task monitoring bell) in standardized locations according to the test manual; however, object placement does not follow the order in which objects are used in the task.

The standard and user-centered NATs were administered across two sessions, separated by at least 1 week but no more than 4 weeks, to minimize the effects of disease progression and practice. The order of conditions was counterbalanced across participants.

NAT Scoring Procedures

Performance was videotaped for subsequent scoring. Previous publications have demonstrated high interrater reliability for NAT variables obtained from numerous clinical populations (Buxbaum et al., 1998; Schwartz et al., 1999, 1998, 2003), including dementia (Giovannetti, Libon, et al., 2002). Additionally, studies of the standard NAT have shown that scores are not affected by participants' age, education, gender, or low-level motor difficulties (Giovannetti, Libon, et al.,, 2002; Schwartz et al., 2002, 2003). For the present study, the following scores were collected for both NATs.

Accomplishment score. This was the percentage of task steps completed with or without error. Accomplishment scores were obtained for the entire NAT and each NAT item.

NAT score. This score reflects the participant's overall level of performance. This score combines the accomplishment score with the sum of a subset of key errors that have been shown to occur frequently in neurologically impaired patients and reliably distinguish patient from healthy populations. A score ranging from 0 (accomplishment score < 50% and 0 or more errors) to 6 (accomplishment score = 100% and < 2 errors) is assigned to each NAT item and summed to equal the NAT Score (range = 0–18; Schwartz et al., 2003). According to norms for older adults, a NAT score below 14 indicates impairment (Sestito, Schmidt, Gallo, Giovannetti, & Libon, 2005).

Comprehensive error score (CES). The CES is the total number of errors made on the NAT, including omissions and commissions. All error categories are described in Table 1. Readers should refer to the NAT manual and earlier publications (Buxbaum et al., 1998; Giovannetti, Libon, et al, 2002; Schwartz et al., 1998, 1999, 2003) for more details on error types. As shown in Table 1, NAT error types may be grouped as omission versus commission. Furthermore, commission errors that occurred infrequently were combined into a single "other" error category (e.g., quality, gesture substitution, spatial misestimation, and tool omission). Total CES (i.e., all error types), total omissions, and total commissions were obtained for the entire NAT and each NAT item. Totals for individual commission error types were obtained for only the entire NAT.

Completion time. This was the number of seconds the participant spent working on the entire NAT. Time data were collected from videotape counters. Timing began when the participant initiated the first task step of each item and ended at the point she or he indicated she or he was finished with each item.

Monitoring bell. Participants were assigned one point for correctly ringing the bell at the end of each item in the user-centered condition (range = 0–3). This variable was obtained only on the user-centered NAT.

Neuropsychological Assessment

The MMSE (Folstein et al., 1975), Geriatric Depression Scale (Yesavage, 1986), and a core set of neuropsychological tests were administered to all participants as part of their clinical evaluation. Table 2 provides a description of the neuropsychological measures. Caregiver reports of patients' everyday functioning in the home (ADL/IADL; IADL = instrumental activities of daily living; Lawton & Brody, 1969) were also obtained.

Data Analysis

Differences between the standard and user-centered conditions were examined with paired-sample *t* tests. Ordinal level variables (total NAT score) and interval level variables that were not normally distributed and unable to be transformed were analyzed with Wilcoxon signed ranks tests. For small samples, the power efficiency of the Wilcoxon is nearly 95% of the paired-sample *t* test (Seigal & Castellan, 1988). Therefore, effect sizes for all standard versus user-centered analyses were estimated by Cohen's *d* calculations (.2 = small; .5 = medium; .8 = large; Cohen, 1988).

To examine whether the user-centered condition had a specific effect on particular NAT items or error types, we performed repeated measures analyses of variance (ANOVAs). Differences across NAT items were assessed using two ANOVAs with NAT condition (standard vs. user-centered) and NAT item (1 vs. 2 vs. 3) as the repeated independent variables. CES was the dependent variable for the first ANOVA and accomplishment score was the dependent variable for the second ANOVA. A Condition (standard vs. user-centered) × Error Type (omission vs. commission) ANOVA was also performed with error rate as the dependent variable. The required statistical assumptions of ANOVA were not met because the variables were not normally distributed and some were unable to be transformed. Therefore, scores were ranked, and ANOVAs were performed on rank scores (Akritas & Arnold, 1994). Post hoc comparisons of commission error types (substitution, anticipation, perseveration, action addition, and other) between the standard and user-centered conditions were performed with Wilcoxon signed ranks tests because several of these variables were non-normal.

Finally, a CES difference score was calculated between the standard NAT and user-centered NAT (CES difference score =

Table 1
Definitions and Examples of Naturalistic Action Test (NAT) Error Categories

Error type	Definitions	Examples from toast and coffee and present tasks
Omission	A step or subtask is not performed.	Does not add sugar to coffee
Commission		
Substitution	Semantically related or perceptually similar alternate object used in place of target object.	Spreads butter on toast with spoon instead of knife
Sequence	Anticipation of a step that entails a subsequent omission; steps or subtasks are performed in reverse order.	Applies butter on bread, without first toasting bread; applies jelly on bread, then applies butter
Perseveration	A step or subtask is performed more than once; an action is performed repetitively or for an excessive amount of time.	Toasts more than 1 slice of bread
Action–addition	Performance of an action not readily interpreted as a task step.	Eats toast; drinks coffee
Quality	Task performance is grossly inadequate.	Pours too much cream into coffee so that the cup overflows
Gesture substitution	Correct object is used, but with an inappropriate gesture.	Grasps knife incorrectly
Spatial misorientation	Object is misoriented relative to the participant's hand or another object.	Misorients wrapping paper with respect to the gift
Spatial misestimation	The spatial relationship between objects is incorrect.	Cuts too small a piece of wrapping paper
Tool omission	Action is performed without the appropriate object	Rips wrapping paper (i.e., does not use scissors)

Table 2
Neuropsychological Protocol

Test	Description	References
	Executive functions	
Boston Revision of the Wechsler Memory Scale—Mental Control subtest	The accuracy of performance on 3 nonautomatized tasks (months backward, alphabet rhyming, alphabet visualization) was calculated with the following algorithm: [1 − (false positives + misses)/(no. possible correct)] × 100.	Cloud et al., 1994; Lamar et al., 2002
Phonemic word list generation	The dependent variable is the number of words produced in 60 s beginning with F, A, or S, excluding proper nouns.	Spreen & Strauss, 1991
	Language	
Boston Naming Test	The dependent variable is the number of pictures correctly named.	Kaplan et al., 1983
Animal Naming—Association Index	This scoring technique quantifies the degree of association between successive responses produced on the animal category naming test.	Giovannetti et al., 1997
	Episodic memory	
Philadelphia (Repeatable) Verbal Learning Test	Participants were asked to remember a 9-word list, as on the California Verbal Learning Test. The dependent variables included total words recalled across Trials 1–5 and the accuracy on the delayed recognition memory task (Recognition Discriminability).	Libon et al., 2005
	Visuoconstructional skills	
Clock Drawing Test	Participants were asked to (a) draw a clock with the hands set to 10 after 11 and (b) copy a drawing of a clock. Ten possible errors were scored on each trial.	Libon et al., 1996

[standard NAT CES − user-centered NAT CES]/ standard NAT CES). A positive difference score reflected a lower CES in the user-centered condition (i.e., improvement). Difference scores for omission and commission errors were also calculated separately. To assess the patient characteristics associated with benefit from environmental adaptations, we performed correlation analyses to explore relations among CES difference scores and neuropsychological test scores.

Results

Characteristics of the Sample

Participants ($N = 46$) had an average age of 80 years ($SD = 6.1$) and 11.6 years of education ($SD = 1.9$). The mean MMSE score was 21.5 ($SD = 4.4$), suggesting mild–moderate overall impairment. According to caregiver reports, participants were mildly–moderately impaired on ADL (maximum possible score = 6; $M = 4.9$, $SD = 1.5$) and moderately–severely impaired on IADL (maximum possible score = 17; $M = 8.7$, $SD = 4.5$) in the home.[1] Neuropsychological test scores are reported in Table 3.

Standard NAT Performance

Mean scores on the standard NAT are shown in Table 4. Relative to published norms, all mean scores fell within the impaired range (i.e., ±2 *SD* cut scores). Furthermore, all standard NAT scores, as well as the distribution of error types, were within the range of those previously reported for mildly to moderately impaired dementia participants (Giovannetti, Libon, et al., 2002, Giovannetti, Schmidt, et al., 2006). Last, the standard NAT score significantly correlated with caregivers' reports of ADL ($r = .31$, $p = .04$) and IADL ($r = .44$, $p < .01$) functioning in the home.

Standard NAT Versus User-Centered NAT: Overall Performance

Table 4 also shows that NAT scores were significantly higher on the user-centered condition (mean ranks of 19.6 vs. 24.5). In fact, a significantly smaller proportion of participants fell within the impaired range on the user-centered NAT (39%) than the standard NAT (67%), $\chi^2(1, N = 46) = 8.1$, $p < .01$. Accomplishment scores also were significantly higher (mean ranks of 15.8 vs. 20.2), and the mean accomplishment score in the user-centered condition fell above the cut score for impairment. Table 4 also shows that CES were significantly lower (mean ranks of 19.8 vs. 14.8) in the user-centered condition. However, time to completion did not differ across the conditions (mean ranks of 21.1 vs. 25.9).

Standard NAT Versus User-Centered NAT: Item Effects

Mean CES across the NAT items are shown in Figure 2. A Condition × NAT Item (1 vs. 2 vs. 3) ANOVA with CES as the

[1] It is worth noting that the 6 participants who did not return for follow-up testing and were not included in the analyses of this study were not strikingly different from the larger group on any demographic variable (mean age = 81.4, $SD = 3.9$; mean years of education = 12.2, $SD = 2.5$; mean MMSE score = 20.2, $SD = 3.0$; mean ADL score = 4.6, $SD = 1.6$; mean IADL score = 10.0, $SD = 6.4$). Although we did not follow up with these participants, we have no reason to suspect that they were meaningfully different from the participants who completed the study.

Table 3
Mean Neuropsychological Test Scores for the Sample and Normative Data From Elderly Controls

Test	AD participants		Normative scores	
	M	*SD*	*M*	*SD*
Geriatric Depression Scale	6.0	6.2	5.75[a]	4.34
WMS Acl	62.6	26.8	91.14	10.62
Clock-drawing errors	4.9	3.1	1.5	1.5
FAS	21.3	11.0	35.27	3.28
Boston Naming Test	35.8	14.1	53.73	6.97
Animal Naming	9.1	4.5	19.94	3.99
PVLT 1–5	20.5	6.7	32.48	5.20
Recognition Discriminability	70.9	18.1	96.61	4.00

Note. WMS Acl = Wechsler Memory Scale—Mental Control Subtest Accuracy Index; FAS = phonemic word list generation; PVLT 1–5 = Philadelphia Verbal Learning Test Trials 1–5.
[a] Spreen and Strauss, 1998; all other normative data are taken from Price et al., 2005, and Libon et al., 2004.

dependent variable showed significant effects of condition, $F(1, 42) = 29.0$, $p < .01$, and item, $F(2, 41) = 93.7$, $p < .01$, but the interaction was not significant, $F(2, 41) = 0.44$, $p = .65$. Post hoc analyses of the item effect patterned as follows: Item 2 (mean rank = 88) < Item 1 (mean rank = 120) < Item 3 (mean rank = 186). The same pattern of results was obtained when accomplishment score was analyzed as the dependent variable: condition, $F(1, 42) = 6.2$, $p = .02$; item, $F(2, 41) = 39.5$, $p < .01$; interaction, $F(2, 41) = 1.5$, $p = .24$. In summary, the nonsignificant interaction effects suggest that the user-centered condition comparably improved performance across the three NAT items.

Standard NAT Versus User-Centered NAT: Error Types

Mean omission and commission errors across the NAT conditions are shown in Figure 3. A Condition × Error Type (omission vs. commission) repeated measure ANOVA showed a significant effect of both condition, $F(1, 41) = 19.3$, $p < .001$, and error type, $F(1, 41) = 21.1$, $p < .001$, with a higher rate of commissions than omissions across both conditions (mean ranks of 106.3 vs. 69.53). The Condition × Error Type interaction was nonsignificant, $F(1, 41) = .15$, $p = .70$; omission and commission errors were comparably lower in the user-centered condition.

Mean commission rates are shown in Table 5. Post hoc analyses comparing each error type across conditions showed significantly lower rates of substitutions (mean ranks of 18.0 vs. 11.9) and additions (mean ranks of 18.1 vs. 12.2) in the user-centered condition. No other differences were statistically significant.

CES Difference Scores and Neuropsychological Measures

There were no significant correlations between any of the CES difference scores (total, omission, and commission) and neuropsychological variables ($r < .27$, $p > .08$, for all).

Monitoring Bell

The majority of participants (76%) rang the monitoring bell for at least one NAT item. Twenty percent of participants rang the bell for every item, 38% for two items, and 18% for only one item. The total number of times a participant rang the bell (range, 0–3) was significantly positively correlated with the CES difference score ($r = .36$, $p = .02$). Thus, participants who more frequently acknowledged the monitoring cue showed the greatest improvement in the user-center condition.

Discussion

To our knowledge, this is the first group study that has directly compared performance on everyday tasks with and without environmental adaptations in AD. Our results demonstrated that relatively simple environmental adaptations that

Table 4
Mean Scores on the Standard Naturalistic Action Test (NAT) Versus User-Centered NAT

Measure	Standard NAT		User-centered NAT		Wilcoxon signed ranks		Effect size
	M	*SD*	*M*	*SD*	*Z*	*p*	(*d*)
NAT score[a]	10.5	5.3	12.5	5.3	−3.0	.003	.47
Accomplishment score[b]	67.2	28.0	76.9	23.3	−3.1	.002	.54
Comprehensive error score[c]	18.5	10.8	13.2	9.9	−4.0	<.001	.70
Time to completion (s)[d]	1025.8	457.2	1003.4	365.6	−0.6	.573	.06

[a] Normative cut score < 14 (Sestito et al., 2005). [b] Normative cut score < 70.0 (Sestito et al., 2005). [c] Normative cut score > 6 (Giovannetti, Libon, & Hart, 2002). [d] Normative scores are not available.

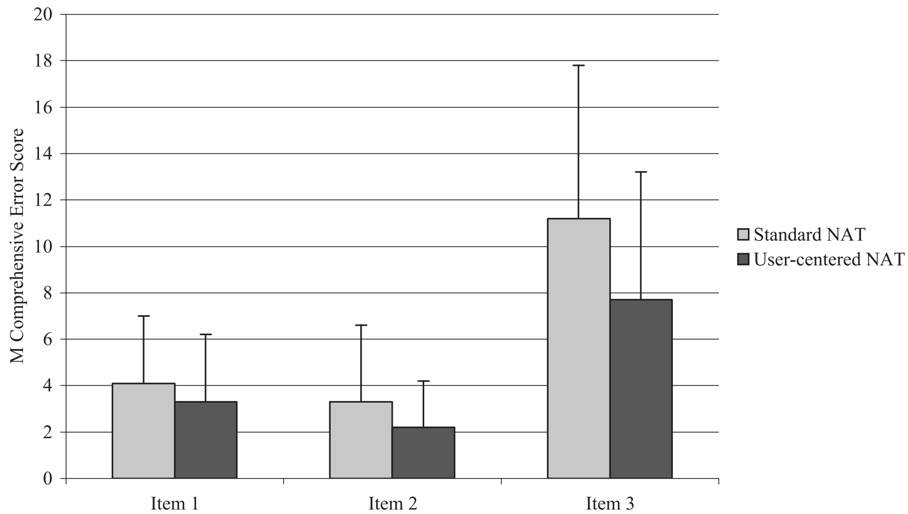

Figure 2. Mean comprehensive error score across Naturalistic Action Test (NAT) item and condition (error bars reflect +1 *SD*). The same pattern of results was obtained for accomplishment scores (i.e., Item 2 > Item 1 > Item 3).

were purposefully designed to (a) increase the compatibility between the task environment and action performance and (b) promote task monitoring, significantly improved task accomplishment, and reduced error rates. Unlike previous reports, the environmental adaptations used in this study did not involve patient training or practice.

It is important to note that the task goals (e.g., make toast and coffee) and all task objects were identical across the two conditions. Furthermore, task performance was scored according to the same criteria in both conditions. Only the environmental adaptations and the cues to utilize these adaptations differed. These adaptations and cues included (a) the placement of the objects, (b) the direction to participants to capitalize upon the placement of the objects by working from left to right, and (c) the monitoring prompt. Clearly, these adaptations were sufficient to facilitate everyday action performance even without practice or training. Consistent with the notion of S-R compatibility, our findings plainly demonstrate that the task environment may be purposefully manipulated to improve everyday action performance in AD. Next, we discuss how the environmental adaptations affected performance.

The environmental adaptations implemented in the user-centered NAT had a comparable effect on each NAT item. The NAT items differ in many ways, including the presence and type of distractor items available, the number of task goals that must be accomplished, the number and type of objects and tools that are needed, the need to search for essential objects that are stored in a drawer, and so on. Nevertheless, the environmental adaptations

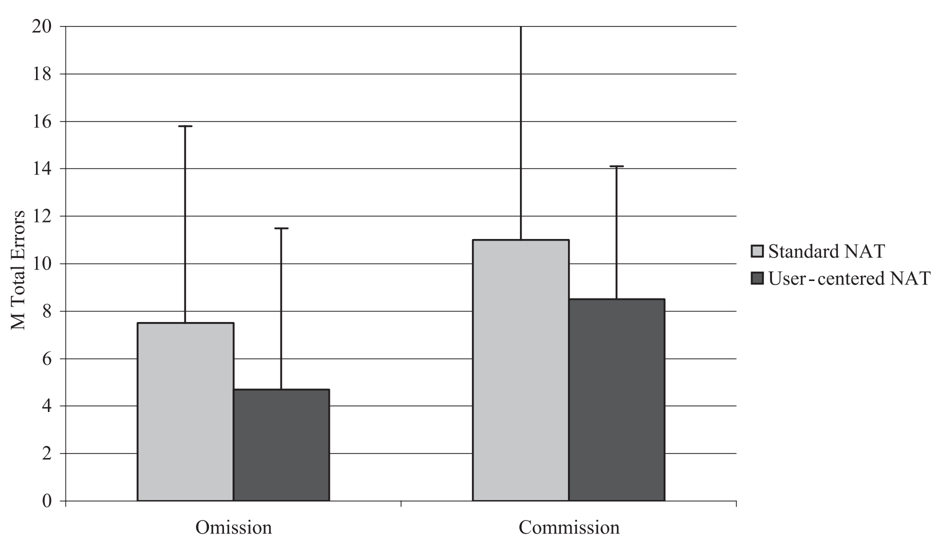

Figure 3. Mean rate of omission and commission errors for standard Naturalistic Action Test (NAT) and user-centered NAT (error bars reflect +1 *SD*).

Table 5
Mean Commission Errors on Standard Naturalistic Action Test (NAT) Versus User-Centered NAT

Error	Standard NAT		User-centered NAT		Wilcoxon signed ranks		Effect size
	M	*SD*	*M*	*SD*	*Z*	*p*	(*d*)
Anticipation	2.8	2.4	2.4	1.4	−0.95	.34	.14
Perseveration	2.0	1.9	2.0	2.2	−0.02	.98	.01
Substitution	2.3	2.2	1.4	1.5	−2.6	.01	.39
Action–addition	2.5	2.6	1.7	2.5	−2.3	.02	.35
Other	1.4	2.6	1.0	2.2	−0.79	.43	.12

used in this study improved performance on each of these very different everyday tasks. This suggests that the principles of increasing S-R compatibility and promoting task monitoring hold promise for improving everyday action performance across a wide range of tasks and settings.

The user-centered adaptations showed a comparable effect on omission and commission errors. Analyses of individual commission error types, however, suggested that the adaptations had a stronger impact on substitution and action addition errors than perseveration and anticipation errors. This was somewhat surprising, as the adaptations were designed to promote task sequencing as well as object selection. It is possible that the ability to avoid distractors (e.g., substitutions) and maintain task-congruent actions (e.g., avoid action additions) is more strongly dependent upon the environmental context (e.g., the availability of objects) than the serial ordering of task steps, which may be more heavily dependent on the integrity of one's internal plan of action or task knowledge. If so, then training and practice, or interventions specifically designed to strengthen task knowledge, may be necessary to reduce the rate of sequence errors in everyday action. These interpretations are speculative and warrant further investigation; however, the results clearly demonstrate that perseveration and anticipation errors were not easily remediated by the environmental adaptations used in this study. Thus, our findings imply that the user-centered strategies may not be appropriate for individuals whose everyday action deficits are characterized by high rates of sequence errors.

We also examined neuropsychological variables to determine which participants benefited most from the user-centered adaptations. However, our results showed no meaningful relations between any of the neuropsychological test scores and improvement on the user-centered NAT (i.e., NAT difference scores). This may have been because only a minority (7%) of our sample did not benefit from the user-centered adaptations. It is also possible that participants who did not show improvement suffered from degraded task or object knowledge, which was not assessed in our neuropsychological protocol. Also, because AD participants demonstrate a relatively homogeneous neuropsychological profile, inclusion of only AD participants may have precluded interesting relations between neuropsychological test scores and improvement from environmental adaptations. Thus, a larger, heterogeneous sample of dementia participants, as well as background tests of task and object knowledge, may have elucidated predictors of improvement from environmental strategies. Future studies should examine these factors in relation to environmental adaptations for everyday functioning.

Although most participants used the monitoring bell at least once, most participants did not consistently use it. Thus, its utility is questionable. However, the number of times a participant used the monitoring bell was significantly related to improvement on the user-centered NAT. That is, participants who used the monitoring bell more frequently showed greater benefit from the user-centered condition than participants who did not use the bell or used it less frequently. This implies that to some degree, everyday action impairment in AD may be attributed to failures in task monitoring. Thus, efforts to promote task monitoring are a practical tactic for improving everyday action performance in AD. However, we acknowledge that without follow-up studies designed to isolate the influence of object arrangement versus error monitoring strategies, the relative importance of these distinct environmental interventions cannot be evaluated.

NAT performance was significantly correlated with ADL–IADL functioning in the home (Giovannetti, Libon, et al., 2002). This supports the validity of the NAT as a measure of real-life functioning in the home. Unlike rating scales, the NAT provides detailed information regarding the specific problems patients faced in everyday action. For instance, Participants 37 and 44 obtained identical scores on the ADL (i.e., score = 5/9) and IADL (i.e., score = 9/17) rating scales. They also both demonstrated comparable overall impairment on the standard NAT (i.e., NAT score = 10). However, a closer look at their NAT error patterns showed that Participant 37 made 17 NAT errors, of which a large majority (94%) were omissions. In contrast, Participant 44 made 22 errors, of which less than one quarter (23%) were omissions. Caregiver ratings generally do not provide such detailed and objective information regarding the nature of patients' action impairment. Thus, we recommend that both caregiver ratings and performance-based measures be included in studies of everyday action impairment. However, we acknowledge the possibility that a patient's familiar home environment and personal objects may facilitate task performance (see Giovannetti, Sestito, et al., 2006); thus performance in the laboratory may underestimate a patient's true abilities. Ideally, if one's goal is to assess real-life functioning, performance-based measures should be administered in the home environment (see Rusted & Sheppard, 2002).

In conclusion, our study is an initial step at understanding everyday action impairment and the effect of environmental strategies on action performance in AD. Future studies must explore whether caregivers and/or patients may successfully implement these adaptations in the home. It is also important for future studies to explore the degree to which additional interventions, such as patient training (e.g., procedural stimulation therapy), augment the benefits of environmental adaptations. Another interesting topic for future research is the effect of environmental manipulations and intervention strategies on neurobiology, as numerous studies have demonstrated environmental factors (e.g., enriched environments) influence hippocampal cell functioning in healthy, aging, and impaired animals, even after relatively brief exposures (Faverjon et al., 2002; Guilarte, Toscano, McGlothan, & Weaver, 2003; Irvine, Logan, Eckert, & Abraham, 2006; Kempermann & Gage, 1999). Although many questions remain unanswered, our results clearly indicate that patients and caregivers should be educated on the environmental adaptations implemented in the user-centered condition (e.g., S-R compatibility, promotion of task monitoring) in an effort to improve everyday functioning in AD.

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