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Objective: Research suggests that dementia patients detect fewer action errors than age-matched controls; however, little is known about the derivation of their error-monitoring difficulties. The aims of the study are to evaluate a novel, task-training action intervention (TT-NAT) designed to increase error monitoring in dementia patients and to pinpoint the relation between error monitoring and neuropsychological processes. ***Method:*** Participants ($n = 45$) with dementia were administered the Standard NAT, a performance-based test requiring completion of three everyday tasks. A second group ($n = 42$) was administered the TT-NAT, which includes a brief training session prior to the commencement of each task. All participants were compared on the following variables: total errors, proportion of errors detected, and proportion of errors corrected. Correlations between error-monitoring variables and neuropsychological tests of executive functioning and language were performed. ***Results:*** TT-NAT participants produced fewer total errors and detected significantly more errors than Standard NAT participants (z = 3.0; $t = 3.36$; $p < .05$). Error detection was strongly related to only the language composite index ($r = .57$, $p = .00$) in the TT-NAT, whereas it was moderately related to both the language ($r = .31$, $p = .04$) and executive composite ($r = .36$, $p = .02$) indices in the Standard NAT condition. ***Conclusion:*** Review of task steps and objects before task performance may be a promising intervention for error-monitoring deficits in dementia patients; this finding has implications for neuropsychological rehabilitation of functional deficits in this population.

Keywords: dementia, naturalistic action, error monitoring, rehabilitation, semantic knowledge

The performance of daily, goal-directed activities necessitates a multitude of cognitive processes, including complex online monitoring of task goals, environmental cues, and outcomes in order to safely complete the actions. As such, everyday actions are particularly sensitive to changes in neurological functioning and represent a significant concern for individuals diagnosed with a dementia (Mioshi et al., 2007; American Psychiatric Association, 2000). Although the egregious error rate generated by dementia patients on everyday tasks remains problematic (Giovannetti, Libon, Buxbaum, & Schwartz, 2002) and relatively unaddressed (Gitlin, Corcoran, Winter, Boyce, & Hauck, 2001; Buxbaum, Schwartz, & Montgomery, 1998), empirical research with older adults suggests that impaired action error detection and correction may signify a more immediate, pressing concern for independent living in this population (Nieuwenhuis et al., 2002; Falkenstein, Hoormann, & Hohnsbein, 2001; Giovannetti, Libon, & Hart, 2002; Bettcher, Giovannetti, MacMullen, & Libon, 2008). The primary aim of this study is to evaluate a task training intervention designed to improve error monitoring in individuals diagnosed with a dementia. The action intervention techniques employed in this study were informed by the neuropsychology and cognitive neuroscience literatures on error-monitoring impairments, semantic knowledge, and task script execution.

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Dementia and Everyday Action

Everyday action is defined as behavior in the service of everyday tasks that entails sequencing multiple steps and utilizing objects to accomplish nested goals (Giovannetti, Libon, Buxbaum, et al., 2002). The diminished ability to perform everyday tasks is a salient problem for neurologically impaired individuals and has been associated with depressive symptomology (Cipher & Clifford, 2004; Kiosses & Alexopoulos, 2005), institutionalization (Knopman, Kitto, Deinard, & Heiring, 1988; Hill, Fillit, Thomas,

& Chang, 2006), and caregiver burden (DeBettignies, Mahurin, & Pirozzolo, 1990). Typically, evaluation of functional impairments in dementia is based on informant-report questionnaires of everyday task performance (Desai, Grossberg, & Sheth, 2004). These assessment methods offer a gross estimation of everyday action performance that can be completed in a relatively short amount of time; however, the information gleaned from these instruments is cursory, underspecified, and prone to reporter bias (Arguelles, Loewenstein, Eisdorfer, & Arguelles, 2001; Zanetti, Geroldi, Frisoni, Bianchetti, & Trabucchi, 1999). Recent studies have addressed these concerns by using performance-based measures in controlled laboratory environments. Results from these studies suggest that dementia patients produce significantly higher error rates and accomplish fewer task goals than controls (Giovannetti, Libon, Buxbaum, et al., 2002). Similar to other neurologically impaired groups, their error patterns are characterized by high rates of omission errors (failure to perform a task step) and commission errors (inaccurate and sequentially incorrect performance of a task step).

Error Monitoring Deficits in Dementia

Research with younger adults indicates that the ramifications of action errors are substantially less taxing if blunders are detected and corrected in an efficient, timely manner (Reason, 1990; Sellen & Norman, 1992; Blavier, Rouy, Nyssen, & de Keyser, 2005); thus, since errors of action may never prove to be wholly avoidable, the ability to accurately and quickly detect one's blunder may represent a more realistic goal for neuropsychological rehabilitation. A disconcerting finding in the literature is that patients diagnosed with a dementia not only generate high error rates but also fail to recognize and rectify a large proportion of these errors. Recent studies using highly controlled and relatively simple laboratory reaction time tasks and forced-choice response tasks report that dementia patients detect and correct significantly fewer errors than age-matched controls (Mathalon, Whitfield, & Ford, 2003; Ito & Kitagawa, 2006), who, in turn, monitor their errors less than healthy younger adults (Band & Kok, 2000; Nieuwenhuis et al., 2002). Results from two naturalistic studies provide support for these findings and further indicate that dementia patients detect between 20% (Giovannetti, Libon, & Hart, 2002) and 34% (Bettcher et al., 2008) of their everyday action errors. Importantly, patients diagnosed with a dementia correct the majority of errors they detect (76%), suggesting that the source of difficulty lies primarily in recognizing and/or evaluating the action error (Bettcher et al., 2008).

Cognitive Foundations of Error Monitoring

Although patients diagnosed with a dementia detect very few of their action errors, little is known about the derivation of their everyday action difficulties, and few studies have been conducted to elucidate a working neuropsychological model of their error monitoring deficits. The cognitive neuroscience and human factors literatures on error monitoring shed some light on this issue in younger adult populations, as they offer taxonomies that isolate the individual's role in the production of errors as well as their likelihood for detecting these action errors (Norman, 1981; Reason, 1990; Zapf & Reason, 1994; Blavier et al., 2005). Within the context of Reason's (1990) model, if an individual formulates an incorrect intention (i.e., he or she does not establish appropriate task parameters), then the subsequent error is referred to as a "mistake." On the other hand, if an individual incorrectly executes a correctly formulated intention, then the resulting error is referred to as a "slip." In order to identify an action as incorrect (i.e., detection), external behavior is monitored and compared to an internal representation of the desired state. As such, intention versus execution errors are inherently associated with very different probabilities for individual detection.

More specifically, mistakes represent the most difficult type of error to detect, as the individual experiences little discrepancy between the outcome and the initial intention. Thus, if an individual establishes an incorrect intention (a mistake), it is unlikely that the associated outcome will trigger a "mismatch" of the desired state. At this point, detections are likely to occur only in the face of third-person intervention, environmental cues, or environmental restrictions (i.e., bottom-up processes; salient information from the environment either cues the individual or prevents them from proceeding with the task). In contrast, "slips" are more readily detected due to the continuity between established intention and appropriate task parameters. Upon producing a slip, the individual may rely on either internal or external feedback to provide evidence of a mismatch between intention and outcome; thus, detection of slips should occur with greater facility due to the fact that the participant has access to bottom-up, environmental information as well as top-down, internal information. In fact, studies of healthy of adults have demonstrated that environmental cues are more efficient in facilitating error detection and recovery for slips as opposed to knowledge-based mistakes (Reason, 1990). In sum, the opportunity for detection of slips is substantially greater than that for mistakes.

Although several studies have investigated the cognitive foundations of error monitoring in younger adults (Reason, 1990; Norman, 1981), there is a dearth of literature on error detection in older adults diagnosed with a dementia (Ito & Kitagawa, 2006). Given the differential error detection profiles associated with slips and mistakes, a comprehensive investigation of error monitoring should examine the neuropsychological constructs that may bolster the likelihood of detecting these errors in dementia. For the current study, our laboratory focused on addressing low rates of error detection due to failures in task knowledge; thus, the cognitive processes most likely associated with this construct will be reviewed.

Task Knowledge

Scripts refer to goal-directed, routine sequences of action that delineate a well-known activity or situation (e.g., toothbrushing). Scripts identify role players and outcomes, and typically involve action sequencing and object utilization (Schank & Abelson, 1977; Allain, Le Gall, Etcharry-Bouyx, Aubin, & Emile, 1999). Knowledge of scripts offers a template for performing everyday tasks and, thus, directly contributes to an individual's ability to effectively interact with and monitor his or her environment.

Research suggests that the manipulation and sequencing of script knowledge requires both executive control/prefrontal cortex and script content knowledge/posterior cortex. For instance, using fMRI, Crozier and colleagues (1999) reported bilateral activations in temporal cortices in addition to prefrontal cortical activation on a series of script sequencing tasks. Cosentino and colleagues also recently confirmed a two-component model of script comprehension in patients diagnosed with frontal-temporal dementia and Alzheimer's disease, and further proposed that the prefrontal cortex retrieves semantic knowledge from the temporal cortex and then assembles and systematizes this information into meaningful goal-directed behavior (Cosentino, Chute, Libon, Moore, & Grossman, 2006). Finally, while accurate performance of everyday tasks requires both components of script comprehension (i.e., task knowledge and executive functions), research suggests that individuals may experience a deficit in only one domain. Sirigu and colleagues (1995, 1996) reported that patients with lesions in the prefrontal cortex retain knowledge of the content of scripts even though they are unable to arrange and appropriately execute this knowledge (see also Chevignard et al., 2000; Zanini, Rumiati, & Shallice, 2002).

Semantic knowledge and, more importantly, script content knowledge are particularly relevant to the error monitoring deficits associated with dementia patients. Work with younger adults suggests that when individuals are unclear of task parameters, or are unsure of how to use the task stimuli, they are less likely to detect and subsequently correct their errors (Scheffers & Coles, 2000; Giovannetti, Schwartz, & Buxbaum, 2007). Among dementia patients with degraded script content knowledge and/or related semantic knowledge, errors in everyday tasks are likely due to mistakes rather than slips—that is, failures in the task plan per se. Failures in the task plan negatively impact error monitoring, as patients cannot compare their behavior to an internal representation of the desired outcome (Blavier et al., 2005). Improvement in error detection was anecdotally reported in a single case study of a patient with severe everyday action difficulties subsequent to carbon monoxide poisoning (Patient FK; Forde, Humphreys, & Remoundou, 2004). His ability to detect his errors increased after training on a tea-making task designed to facilitate his knowledge of the task. Thus, there is reason to propose that brief script training sessions prior to the commencement of everyday activities may promote error monitoring by restoring degraded or incomplete task knowledge and minimizing the production of mistakes.

Current Study

The primary aim of the current study was twofold: (a) to evaluate a task training action intervention designed to increase error monitoring in dementia patients, and (b) to pinpoint the relation between error monitoring and neuropsychological processes in participants who receive the task training intervention. In order to accomplish this, participants were administered a neuropsychological protocol that assessed language functioning, executive control, and episodic memory. In addition, a naturalistic action intervention, referred to as the Task Training NAT (TT-NAT), was conducted with recruited participants and compared to existing data from an empirically validated control condition (Standard NAT; Schwartz et al., 1998; Schwartz, Segal, Veramonti, Ferraro, & Buxbaum, 2002; Giovannetti, Libon, Buxbaum, et al., 2002). Action-error-monitoring rates were evaluated and compared across both conditions. The Standard NAT requires participants to perform three everyday tasks using objects that are placed before them on a U-shaped table. For the purpose of the current study, a novel intervention based on improving script content knowledge was devised. The TT-NAT and Standard NAT involve the same administration and scoring procedures. However, the conditions differ in that a task-training session is implemented prior to the initiation of each NAT task in only the TT-NAT. Specific rehabilitation techniques employed in the TT-NAT include identification and description of objects used in the task as well as presentation of photographed depictions of important task steps. This served to familiarize participants with the task parameters and was designed to improve knowledge of the content of the task.

Our first hypothesis was that the improvements in action script knowledge ("task knowledge") would lead to improved action-error monitoring in dementia patients. Therefore, we predicted that participants performing the TT-NAT would detect and correct a higher proportion of their action errors than dementia participants performing the Standard NAT. Second, we hypothesized that the training in action script knowledge would facilitate error monitoring by reducing the burden on language functioning and semantic knowledge. Therefore, we predicted that monitoring failures in the TT-NAT condition would be strongly related to impaired executive control. Specifically, we predicted that performance on executive control measures would (a) explain a significant portion of variance in error detection and correction rates in the TT-NAT, and (b) explain significantly more error detection/correction variance in the TT-NAT than the Standard NAT.

One additional exploratory analysis was performed. To determine whether episodic memory functioning played a contributory role in TT-NAT performance, post hoc analyses exploring an association between episodic memory ability and error-monitoring variables were conducted. According to standard clinical practices (American Psychiatric Association, 2000), episodic memory functioning represents the keystone to dementia diagnosis; however, a relation between episodic memory and action error detection/correction has yet to be documented (Giovannetti, Libon, & Hart, 2002; Bettcher et al., 2008; Bettcher & Giovannetti, 2009).

Method

Participants

Fifty-four participants were recruited for the current study, but one participant was disqualified due to subsequent determination that she met an exclusion criterion for the study (cortical stroke). Of the remaining 53 individuals, 42 participants were administered the TT-NAT.

Eleven participants were prospectively administered the Standard NAT and were included in a hybrid group with participants selected from a larger database of over 200 participants recruited for prior studies using the Naturalistic Action Test (NAT; Giovannetti, Libon, Buxbaum, et al., 2002; Giovannetti et al., 2006). First, however, these 11 new participants were compared to a group of similar (i.e., matched on age, education, and MMSE) participants from the larger database. This was done to determine whether or not participants recruited for the current study were similar to those in the database who were recruited from different sites in the past. Then, 34 Standard-NAT participants were selected from the database based on the inclusion/exclusion criteria of the current study and the availability of neuropsychological test data. This group of Standard-NAT participants served as a comparison group to evaluate the effect of the TT-NAT. The size of the TT-NAT

($n = 42$) and Standard NAT ($n = 45$) groups provided sufficient power (.79) to detect a medium-large effect when alpha (p value) is set at .05 (Erdfelder, Faul, & Buchner, 1996). For within-group correlation analyses, both groups provide sufficient power (.95 and .96, respectively) to detect large effects (.5) when alpha is set at .05.

Participants were recruited for this study from three sources: outpatient neurology clinics located at Temple Hospital and Drexel College of Medicine as well as general outpatient community referrals. The referrals at all locations were comprised of older adults diagnosed with a neurodegenerative dementia. A diagnostic consensus panel was not available for community referrals; however, all patients from both groups were seen by a neurologist and obtained blood work to rule out reversible conditions and/or metabolic disorders. The primary diagnoses ($n = 80$) were Alzheimer's disease (AD), vascular dementia (VaD), or mixed AD/VaD, although individuals diagnosed with a Parkinson's disease-related dementia were also evaluated ($n = 7$). Participants met the following inclusion criteria: (a) between the ages of 65 and 90; (b) Mini-Mental State Examination (MMSE) $\geq$ 10 and $\leq$26; (c) diagnosis of dementia according to *DSM–IV* criteria (American Psychiatric Association, 2000). The decision to include all dementia diagnoses in the current study was based on two reasons. First, one of the aims of the study was to evaluate the role of specific neuropsychological processes in error monitoring; thus, the inclusion of varied neuropsychological profiles was crucial to isolating the specific locus of difficulty for dementia patients. Second, recent neuropathology studies have reported considerable overlap between dementia diagnostic syndromes (Victoroff, Mack, & Lyness, 1995; Etiene, Kraft, & Ganju, 1998), suggesting that the incidence of a "pure" dementia (e.g., Alzheimer's disease) may be less common than originally believed. As such, all individuals diagnosed with a primary dementia were included in the study.

Participants were not recruited for the study if they had a history of alcohol or illicit drug abuse in the past month; history of epilepsy, cortical stroke, or any significant traumatic brain injury; diagnosis of a primary psychiatric disorder; mental retardation; or were non-English speaking. Information pertinent to both inclusion and exclusion criteria were obtained from a brief interview, medical chart review, and the administration of a brief assessment of global cognitive functioning (i.e., MMSE; Folstein, Folstein, & McHugh, 1975). All participants signed Institutional Review Board approved informed consents and were compensated $30 for the session. Eligible participants were also required to sign a separate form stating that they consented to having their NAT performances videotaped.

Neuropsychological Measures

In order to assess neuropsychological performance, participants' global cognitive functioning, episodic memory, language functioning and semantic knowledge, and executive control abilities were evaluated. A description of these measures is included in Table 1.

Table 1
Neuropsychological Protocol

Test	Description	References
Dementia Severity		
Mini Mental-State Examination (MMSE)	30-item measure of dementia severity. Total scores range from 0–30; higher scores indicate better global cognitive functioning.	Folstein, Folstein, & McHugh (1975)
Executive Functions		
Boston Revision of the Wechsler Memory Scale-Mental Control Subtest (Mental Control)	The accuracy of performance on three nonautomatized tasks (months backward, alphabet rhyming, alphabet visualization) was calculated with the following algorithm: [1-(false positives + misses)/(#possible correct)] × 100.	Lamar et al. (2002)
Phonemic fluency (FAS)	The dependent variable is the number of words produced in 60 s beginning with F, A, or S, excluding proper nouns.	Spreen & Strauss (2006)
Clock Drawing Test	Participants were asked to (1) draw a clock with the hands set to ten after eleven, and (2) copy a drawing of a clock. Ten possible errors were scored on each trial.	Cosentino et al. (2004); Goodglass & Kaplan (1983); Libon et al. (1993); Libon, Malamut, Swenson, Sands, & Cloud (1996)
Language		
Boston Naming Test (BNT)	The dependent variable is the number of pictures correctly named.	Kaplan et al. (1983)
Category Fluency (Animals)	Two dependent variables were calculated: (1) Total number of animals generated in 60 s, and (2) animal association index (AI). The animal association index necessitates a special scoring technique that is believed to measure the semantic organization between successive responses.	Spreen & Strauss (2006); Carew et al. (1997)
Episodic Memory		
Philadelphia (Repeatable) Verbal Learning Test-Discriminability Index (PVLT-Discriminability)	Participants were asked to remember a 9-word list, as on the CVLT. The dependent was the accuracy on the delayed recognition memory task (Recognition Discriminability).	Libon, Mattson, & Glosser (1996)

Everyday Action Measures

The Naturalistic Action Test is a standardized measure of naturalistic action that requires completion of three everyday tasks in the laboratory: (a) prepare toast with butter and jelly and prepare instant coffee with cream and sugar; (b) wrap a gift as a present; (c) prepare a lunchbox with a sandwich, snack, and a drink, and pack a schoolbag with supplies for school. All objects are available on a U-shaped table, which permits easy view and reach of task items. Since the NAT is designed to assess cognitive rather than motor abilities, physical assistance is permitted when necessary; otherwise, the examiner provides no guidance to the participant. In the present study, the NAT is referred to as the "Standard NAT" when it was administered according to the standardized procedures set forth in the test manual.

Prior studies have shown that Standard NAT variables are not affected by education, gender, or motor difficulties (Buxbaum et al., 1998; Giovannetti, Libon, Buxbaum, et al., 2002; Schwartz et al., 1998, 2002; Sestito, Schmidt, Gallo, Giovannetti, & Libon, 2005). To ensure that there were no significant baseline differences in our current sample relative to previous samples collected at different location sites, 11 Standard NATs were collected prospectively in this study (~25% of sample; as discussed in Participants section). These participants were included in the initial randomization of prospective dementia patients and, thus, were collected concurrently with individuals participating in the TT-NAT intervention condition. Specifically, randomization for the initial subset of patients was implemented with a random number generator; after 11 Standard NATs were collected, the remaining patients were administered the TT-NAT. Patients were not informed of the randomization and were all told that they would be participating in a study examining everyday activities and cognitive functioning. The prospective sample of Standard NATs was subsequently compared to a retrospectively collected, age- and education-matched sample of dementia participants. No significant differences were noted for Total Errors, Proportion Detected, or Proportion Detected-Corrected ($p > .05$ for all variables).[1] As such, a hybrid group was formed, consisting of both retrospective ($n = 34$) and prospective ($n = 11$) Standard NATs. This served to increase the power of the study while solidifying the similarities between groups.

The Task Training NAT (TT-NAT) is a novel, theory-based intervention designed to improve script content knowledge and was used in the current study as the primary prospective measure. The TT-NAT is identical to the Standard NAT in administration and design, with the exception of one key difference: The TT-NAT includes a brief (~10 min) training session prior to the commencement of each of the three tasks (~30 min of total training time). The training consisted of the following two components: (a) verbal description and picture presentation identifying all necessary task items and steps, and (b) verbal description and video presentation reviewing all necessary task actions. For example, the first task requires participants to make a cup of instant coffee with cream and sugar, and a single slice of toast with butter and jelly. To suffice Criterion 1 of the training session, participants were shown pictures and provided a brief explanation of the following key items/steps of the coffee task: spooning the coffee grounds into the cup of water, spooning the sugar into the cup of water, pouring the cream into the cup, and stirring the coffee with the spoon. To suffice Criterion 2 of the training session, participants were subsequently shown a video of the researcher performing the same task (videotaped from the participant perspective) and provided with the same brief description offered in the picture section. In order to ensure that all participants understood the task parameters and equate participants on script content knowledge, a pictorial quiz was given at the end of each training session. The quiz was designed to cover the primary components of each task and was reviewed with the participant until he or she answered all questions correctly. Finally, all pictures cues used in the training section of the TT-NAT were placed in front of the patient throughout the duration of the task to prevent decay of task training.[2]

Evaluation of Everyday Action Performance

Video recordings of the Standard NAT were performed at the time of testing and were available for analysis. Participants performing the TT-NAT were also videotaped. All video recordings were viewed and coded for errors of action. Errors of action specifically involve an act or instance that deviates from the prescribed code of behavior. It is an act that fails to achieve what should be done given the procedural context and instructions. The NAT manual describes an extensive coding system for error analysis (Comprehensive Error Score, CES; Schwartz, Buxbaum, Ferraro, Veramonti, & Segal, 2003; Schwartz et al., 1998).

The CES does not capture errors that are not fully executed (i.e., microslip). However, microslips reflect instances of error detection/correction and are highly relevant to the study of error monitoring; thus, they were coded for the present study. Microslips are operationally defined as the initiation and termination of an incorrect action before the error was completed (see also Giovannetti et al., 2007). This includes reaching for or picking up an incorrect item or initiating a behavior that is dissonant with the task goal. For example, picking up, but not using, the garden shears instead of the scissors in the gift-wrapping task would be coded as a microslip. For all analyses, microslips were added to CES errors (i.e., total errors).

Error Detection and Correction

For the proposed study, an error-monitoring coding system modeled on that of previous studies (Hart, Giovannetti, Montgomery, & Schwartz, 1998; Giovannetti, Libon, & Hart, 2002), and recently validated in a study of monitoring deficits in dementia (Bettcher et al., 2008), was utilized for the analysis of error detection and correction. Two raters blind to participant characteristics independently coded NAT videotapes for microslips, error detection, and error correction. Disagreements between the coders were resolved through discussion and/or rereview of videotapes. Interrater reliability was assessed for 15 participants selected randomly from the sample.

[1] Additional analyses were conducted at the end of the study, comparing the prospective and retrospective Standard NATs in the *current* sample (i.e., not utilizing the larger database or matching for age and education). No differences between the groups were noted for age, education, MMSE, or action monitoring variables.

[2] Please see lab website at http://www.temple.edu/cogneurolab/projects/index.htm to view or download task stimuli and training materials.

Error detection. By definition, all microslips are considered "detected." However, each CES error was further classified as "detected" or "undetected." Error detection is operationally defined as an acknowledgment of mismatch between an individual's executed activity and the prescribed code of behavior for the task. This acknowledgment may present itself in three forms: verbalization, failed correction attempt, or an actual correction. To be considered evidence for detection, a verbalization must indicate recognition of the error or the possibility of task mismatch. (i.e., "I think you said to add sugar and cream to the coffee, but I'm adding only cream"). The second mode of acknowledgment involves physical effort to alter the consequences of the error; however, it does not necessitate that the participant successfully rectify the error. For example, if an individual places cookies in the pencil case, then proceeds to remove them and place them in the drawer (target = lunchbox), the action is classified as detected even though the participant failed to accurately correct the error. That is, by removing the cookies from the pencil case, he or she acknowledges the inaccuracy of the action but fails to properly resolve the problem. Finally, for the purpose of this study, all corrections were considered "detected." The proportion of total errors (i.e., CES + microslips) that was detected was calculated for each participant (proportion detected = total errors detected/total errors).

Error correction. Again, all microslips, by definition, are considered "corrected." Therefore, only CES errors required further coding as either "corrected" versus "uncorrected." A "correction" was coded when an act was accurately "undone." Failed attempts to correct errors were coded as "uncorrected." For example, adding jelly to the bread before toasting was coded as undetected and uncorrected. This sequence error was coded as "detected" and "corrected" if the participant attempted to scrape off the jelly before toasting (i.e., undoing the error). It was coded as "detected" and "uncorrected" if the participant made only a verbal comment about the erroneous action ("I know this isn't right").

There is obvious overlap between the detection and correction categories, as we assumed that all corrected errors also were "detected." Therefore, with respect to correction, we were interested in knowing the proportion of "detected" errors that were subsequently corrected. This was calculated as follows: Proportion Detected-Corrected = Total Errors Corrected/Total Errors Detected (See Table 2 for a list of the dependent variables).

Procedure

All participants were tested at the Cognitive Neuropsychology Laboratory at either Temple University or Drexel University in Philadelphia. All participants were administered a neuropsychological protocol, followed by the TT-NAT intervention (or Standard NAT). The testing session lasted approximately 2.5–3 hr.

Statistical Analyses

Preliminary analyses included a calculation of the mean and standard deviation for each variable. The normality of all variables was examined to verify the assumptions for parametric statistical tests. In order to answer the question of whether the TT-NAT intervention is associated with higher rates of error detection and correction compared to the Standard NAT, separate between-sample comparisons were performed for NAT Proportion Detected and Proportion Detected-Corrected. Independent *t*-tests were used for variables that were normally distributed (or could be transformed); Mann–Whitney tests were used for variables that did not meet assumptions of normality. Effect sizes for all TT-NAT versus Standard NAT analyses were estimated using Cohen's *d* calculations (Cohen, 1988).

To address the hypothesis that error-monitoring behavior in dementia patients who received the TT-NAT would be related to executive control processes, a composite score was calculated for executive control indices. Raw neuropsychological data from the Clock Drawing Test, Mental Control, and Word Generation Task were significantly correlated (rs $> .40$); therefore, they were converted to z-scores (based on data from the entire sample) and then averaged to create an executive control composite score. The purpose of this calculation was to reduce collinearity between these neuropsychological variables and to reduce the number of analyses performed. A similar procedure was conducted for the language/semantic knowledge measures that were correlated (i.e., Category Fluency and Boston Naming Test; $r = .59$, $p = .00$). Z-scores (based on the entire sample) for the Category Fluency and Boston Naming Test were averaged to create a language/semantic knowledge composite score. The AI measure was not correlated with any neuropsychological measured utilized in the study; thus, it was analyzed separately from the composite indices.

Next, Pearson correlation coefficients were calculated to evaluate the relations between TT-NAT Proportion Detected and neuropsychological test scores (i.e., MMSE, composite indices, AI). Similarly, the relation between TT-NAT Proportion Detected-Corrected and the same neuropsychological test scores was also evaluated. Two participants were missing more than two neuropsychological test scores and were not included in correlation/regression analyses. Verbal fluency measures were missing for two participants and were replaced using a regression equation derived from the neuropsychological data of participants without missing data. This method also was used to replace the missing nonautomatized mental control score for two other participants.

When more than one neuropsychological variable was significantly correlated to the Detection/Correction variables (i.e., Standard NAT Proportion Detected and Standard NAT Proportion Detected-Corrected), stepwise regression analyses were performed to determine the multivariate relations (i.e., which cognitive measures or combinations of measures were predictive of error monitoring). Executive composite, language composite, and MMSE scores were entered in the stepwise regressions.

Table 2
Error Detection and Correction Variables

NAT Errors
Total Errors (CES Errors + Microslips)
Error Detection
Proportion Detected (Total Detected/Total Errors)
Error Correction
Proportion Detected-Corrected (Total Corrected/Total Detected)

Note. CES = Comprehensive Error Score.

Results

Sample Characteristics

As shown in Table 3, the primary dementia groups (n = 42 TT-NAT participants; n = 45 Standard NAT participants) were comparable in age and dementia severity; they also did not significantly differ in the distribution of men versus women or ethnicity (i.e., proportion of African Americans vs. Caucasians). On average, the TT-NAT participants had a higher level of education; however, consistent with prior studies (Buxbaum et al., 1998; Schwartz et al., 1999), correlations between education and NAT variables were not significant (for all groups: Percent Detected, $r = .07$, $p = .48$; Percent Detected-Corrected, $r = .11$; $p = .23$). Therefore the modest between-groups difference for education was inconsequential for the primary analyses.

Interrater Reliability

The raters demonstrated 97.8% agreement in coding all errors as detected or corrected (Cohen's kappa, .95).

NAT Errors

On average, dementia participants produced significantly fewer total errors in the Task Training (TT-NAT; $M = 9.8$, $SD = 7.4$) Condition relative to the Standard NAT Condition ($M = 16.9$; $SD = 11.9$; $z = -3.0$, $p = .002$; $d = .72$).

Hypothesis 1: TT-NAT and Rates of Error Monitoring

Consistent with our prediction, participants performing the TT-NAT detected a higher proportion of their action errors than dementia participants performing the Standard NAT (See Table 4). Unlike previous studies of the Standard NAT (Bettcher et al., 2008; Giovannetti, Libon, & Hart, 2002), total error rate was significantly related to the proportion of errors detected in this sample[3] ($r = -.33$), such that participants who made more errors also detected fewer errors. An ANCOVA was conducted with total errors as the covariate, $F(1, 83) = 4.9$, $p = .03$; the effect of intervention condition (i.e., Standard vs. TT-NAT) remained significant, $F(1, 83) = 6.2$, $p = .02$. Thus, the high error detection in the TT-NAT cannot be attributed to the lower error rate in this condition; instead, it appears that the TT-NAT intervention both lowered error rates and improved error detection.

Although we predicted that error correction rates (i.e., Proportion Detected-Corrected) would also be higher in the TT-NAT condition relative to the Standard NAT condition, these rates were comparable between the two groups (See Table 4). The participants' total error rate was not significantly related to the proportion of errors corrected out of detected ($r = -.16$, $p = .12$) in the entire sample. Consistent with previous studies of error monitoring (Giovannetti, Libon & Hart, 2002; Bettcher et al., 2008), dementia participants corrected the majority of errors they detected in both conditions.

Hypothesis 2: TT-NAT and Neuropsychological Processes

Counter to prediction, error monitoring variables in the TT-NAT condition were not related to executive control measures.[4] Notably, a significant and robust relation between Proportion Detected and the language/semantic knowledge composite index was found ($r = .57$, $p = .00$). Also of note, Proportion Detected and Proportion Detected-Corrected were not related to the MMSE ($r = .14$ and $r_s = -.02$, respectively), while Total Errors was significantly correlated with the MMSE ($r = -.56$, $p = .00$).

As shown in Table 5, Proportion Detected-Corrected (i.e., proportion of errors corrected, of the ones detected), was not associated with any neuropsychological measure or composite index measured in the TT-NAT condition. The AI score (not shown in the table) was not related to any monitoring variable assessed (rs $< .20$).

As a means of comparison, correlation and regression analyses were also conducted for the Standard NAT. The MMSE was related to Proportion Detected ($r = .38$, $p = .01$), Proportion Detected-Corrected ($r_s = .30$, $p = .05$), and Total Errors ($r = -.49$, $p = .001$). Partial correlations (controlling for MMSE) were conducted to isolate the relations between the neuropsychological composite indices and error-monitoring variables in the Standard NAT condition. Similar to the findings in the TT-NAT condition, neither of the neuropsychological composite indices was related to Proportion Detected-Corrected. As shown in Table 5, Proportion Detected was significantly related to both the executive control and language/semantic knowledge composite indices. Although the relation between the language composite and Proportion Detected was stronger in the TT-NAT condition relative to the Standard NAT, this difference was not statistically significant ($p = .14$). A regression analysis indicated that the best model for Proportion Detected in the Standard NAT condition accounted for only 12% of the variance and included the executive control composite as the sole predictor ($\beta = .35$; $t = 2.34$; $p = .02$).

Exploratory Analysis: Episodic Memory

To determine whether episodic memory functioning played a contributory role in TT-NAT performance, post hoc analyses comparing the PVLT recognition discriminability index and Proportion Detected/Proportion Detected-Corrected were conducted. Consistent with previous findings, episodic memory performance was not related to error monitoring variables in the Standard NAT condition (ps $> .05$), nor was it related to Proportion Detected-Corrected in the TT-NAT; however, Proportion Detected on the TT-NAT and the PVLT index were significantly correlated ($r = .40$, $p = .01$; controlling for MMSE, $r = .37$, $p = .02$), suggesting that better episodic memory abilities were associated with a higher proportion of detected action errors in the TT-NAT condition.

Discussion

Consistent with our prediction, dementia participants in the TT-NAT condition performed significantly better than participants in the Standard NAT condition. Specifically, TT-NAT participants

[3] Note that this sample included participants who were administered either the Standard-NAT or the TT-NAT.

[4] Results remained the same when examining the relationship between error monitoring variables and *individual* executive control measures (rather than composite indices).

Table 3
Demographic and Neuropsychological Data Across Groups

	Group	Analysis	
	TT-NAT *M* (*SD*)	Standard NAT *M* (*SD*)	TT-NAT vs Standard NAT *t* value
Age	76 (6.2)	78 (5.7)	−1.9
Education	13 (2.9)	12 (1.9)	3.2*
MMSE (Mini-Mental Status)	22 (3.2)	22 (3.2)	.19
Memory			
PVLT-Discriminability	75 (16.4)	76 (14.0)	−.36
Executive Functions			
Mental Control	65 (23.5)	65 (23.8)	.11
Phonemic Fluency (FAS)	24 (13.4)	22 (10.7)	.92
Clock Drawing	5 (2.3)	5 (2.7)	.75
Language			
Boston Naming Test (BNT)	36 (12.9)	38 (13.1)	−.85
Category Fluency (Animals)	10 (4.4)	10 (4.5)	.51

Note. TT-NAT = Task Training Naturalistic Action Test; Standard NAT = Standard Naturalistic Action Test.
* $p < .05$.

produced fewer overall errors and detected more errors than Standard NAT participants. This suggests a significant benefit of the task training condition for overall error production and detection. No differences were noted for error correction analyses, indicating that while participants detected more errors in the TT-NAT condition, they did not correct proportionally more errors than Standard NAT participants. The results from this study have direct implications for both caregiver training and neuropsychological rehabilitation, as patients diagnosed with a dementia may benefit from targeted interventions that address impoverished task knowledge.

TT-NAT: Increasing Detection, One Picture at a Time

The Task Training NAT (TT-NAT) was designed to ameliorate error-monitoring problems due to degradation in task knowledge. The intervention was associated with markedly higher error detection rates compared to the standard condition, with dementia participants detecting nearly half of their action errors (48.6%). In evaluating the TT-NAT's efficacy, it is imperative to consider how the TT-NAT intervention induced higher error detection rates. As such, the TT-NAT will be appraised in terms of both the design and the outcome of the intervention.

The design of the TT-NAT offered numerous advantages over the Standard NAT that likely boosted error detection in participants. First, the intervention provided a scripted, pictorial description of the objects used in each task. This minimized the effect of degraded object knowledge and degraded object-action associations on performance, as it identified the appropriate objects necessary to complete each task as well as which objects should be used together (e.g., "For the coffee, you spoon the coffee grounds into the cup of water. These are the instant coffee grounds, and this is the cup of water"). Second, the training also included a video presentation of the task, filmed from the participant's perspective. This reduced the need for participants to mentally rotate the actions depicted in the video and, thereby, increased the continuity between the training and the required tasks. Third, the intervention also incorporated a salient visual component to each of the training steps (e.g., pictorial display, video presentation, and picture quiz). This ensured that the modality of training was consistent with the modality of testing. These three factors may have been helpful in improving participants' script content knowledge and increasing the likelihood for error detection.

In addition to the design of the TT-NAT, the outcome of the intervention necessitates further review. Although the overarching

Table 4
Means and Standard Deviations for Action Monitoring Variables Across Primary Groups

	TT-NAT (n = 42)		Standard NAT (n = 45)				
	M	*SD*	*M*	*SD*	z/t	*p* value	Effect size/*d*
Total errors	9.8	7.4	16.9	11.9	$z = -3.00$	0.002	0.72
Proportion detected (total detected/total errors)	48.62	25.89	32.68	17.62	$t = 3.36$	0.001	0.72
Proportion detected-corrected (total corrected/total detected)	85.3	19.73	83.26	23.06	$z = -0.29$	0.76	0.1

Table 5
Correlations for Neuropsychological and Action Monitoring Variables by Group

	TT-NAT		Standard NAT[a]	
Composite	Proportion Detected r	Proportion Detected-Corrected r_s	Proportion Detected r_{pc}	Proportion Detected-Corrected r_{pc}
Language Comp	$.57^{**}$	−.15	$.31^{*}$	.09
Executive Comp	.24	.11	$.36^{**}$	.08

[a] Partial correlations conducted, controlling for Mini-Mental Status Exam (MMSE).
* $p < .05$. ** $p < .025$.

goal of the study was to evaluate whether a theory-based intervention could improve error monitoring in dementia, the mechanisms underlying this intervention are also important considerations. The design of the TT-NAT was couched in the theory that improving task knowledge should reduce the likelihood of mistakes (i.e., errors due to a faulty task script or intention; Reason, 1990). The intervention aimed to improve a participant's ability to detect an error by strengthening the task script and minimizing errors due to faulty intentions. As discussed in the introduction, the opportunity for the detection of slips (i.e., execution errors) is substantially greater than for the detection of mistakes (i.e., intention errors) due to the continuity between task parameters and the individual's action plan. By improving an individuals' knowledge about the task, error detection should theoretically ensue with greater facility.

The results of the current study offer evidence both for and against the suggestion that the mechanism by which the TT-NAT exerted its benefit was through the enhancement of "script content" or task knowledge. The pattern of correlations observed between neuropsychological test scores and error-monitoring variables in the TT-NAT (discussed more comprehensively in later sections) did not clearly suggest a disproportionate reduction of mistakes in the TT-NAT condition. That is, contrary to prediction, the task training did not weaken the association between error monitoring and language/knowledge abilities and strengthen the association between error monitoring and executive control. It is possible that mistakes were not specifically reduced in the TT-NAT and that participants continued to produce a combination of slips and mistakes. Despite their improved overall performance, participants in the TT-NAT condition did not detect the majority of errors produced; as such, a combined, but not targeted reduction in mistakes (and slips) remains possible. Evidence for the hypothesis that the TT-NAT circumvented task knowledge deficits is that the intervention was associated with markedly higher error-detection rates than the Standard-NAT—a pattern that is strongly associated with the production of slips rather than mistakes in the cognitive neuroscience literature (Blavier et al., 2005; Reason, 1990; Sellen & Norman, 1992, Sellen, 1994). It is relevant to highlight, however, that error behavior is multifactorial, such that the same error could result from planning or execution difficulties (Reason, 2002). Similarly, while error monitoring should be easier and occur more frequently when an individual maintains an intact task representation, it is not solely indicative of the integrity of the initial plan. Thus, without a definitive measure of mistakes versus slips, this issue cannot be completely resolved in the current study. Importantly, it appears that by training dementia participants on the content of the task, their overt action error detections improve.

The Role of Language and Executive Control in TT-NAT Detections

Pursuant to the evaluation of the TT-NAT design and outcome, the results also beckon the question of how this intervention was successful for a range of dementia subtypes with varying neuropsychological impairments. As stated, we predicted that the TT-NAT's mechanism of action would be its ability to circumvent error-monitoring problems due to degraded task knowledge. As such, error-monitoring breakdowns subsequent to the training should be due to executive dysfunction rather than semantic knowledge/language impairments. The results suggest a different and potentially more parsimonious evaluation of the intervention, namely, relatively spared and accessible linguistic abilities seem to be a crucial prerequisite for the training session to work. To clarify, the better a participant performed on language tests prior to the training, the more likely they were to detect their errors in the TT-NAT condition. This composite index explained more variance in TT-NAT condition relative to the Standard NAT condition (although this was not statistically significant), suggesting that semantic knowledge/linguistic abilities are necessary to significantly benefit from the intervention. It may be that participants interpreted the training within the context of their own task representations, regardless of how accurate or complete these internal representations were (Funnell, 2001). Thus, in order to cognitively appreciate the training session, retrievable knowledge of objects and their respective uses was advantageous. In addition, the strong relation between the language/semantic knowledge composite and error-detection rates indicates that while task knowledge impairments were ameliorated, they were not completely circumvented by the intervention.

Another important facet of this study is the lack of connection between executive control processes and error detection in the TT-NAT. This represents a departure from the Standard NAT condition, where both tests of language and executive control buttressed error-monitoring performance. This result was surprising, as detecting an error often necessitates a host of executive processes, including attention, inhibition, and working memory (Miller & Cohen, 2001). It is unclear why detection rates were not related to executive control processes in the TT-NAT; however, the potential reduction in planning errors may be germane to this finding (or lack thereof). According to cognitive neuroscience models of error production and monitoring, slips are easier to detect and evaluate than planning errors/mistakes (Norman, 1981; Reason, 1990; Zapf & Reason, 1994; Blavier et al., 2005). Although we postulated that executive control processes were likely related to the detection of slips, it may simply be that the detection process is cognitively less taxing and requires less mental flexibility when participants are trained on task parameters. Furthermore, the provision of a cue card outlining the task components may have reduced the need to hold competing action plans in working memory. Although this may seem relatively straightforward and intuitive, it is an important finding for circumventing and, ultimately, rehabilitating error-monitoring failures in dementia. It suggests that the intervention may be widely used with participants who have mild to moderate (but not severe) language impairments, and that the efficacy of the intervention is not deleteriously affected by executive dysfunction in participants. This is not to suggest that executive control processes do not play a pivotal role in everyday action monitoring; clearly, prior studies have underscored the importance of executive functions in detecting and subsequently correcting errors (Bettcher et al., 2008; Miller & Cohen, 2001); however, in the face of a cognitive intervention, the demand and burden on these processes may be lower.

An unanticipated, but not all together surprising, finding was the modest association between proportion detected and episodic memory functioning in TT-NAT participants. This relation was not observed in the Standard NAT and has not been reported in previous studies (Bettcher et al., 2008; Giovannetti, Libon, & Hart, 2002). This finding suggests that participants' capacity to encode new information was related to their propensity to detect an action error. The association suggests a role, albeit small, for episodic memory functioning in the TT-NAT intervention. Although cue cards were provided to participants to minimize and circumvent the burden of episodic memory deficits, the training does necessitate a basic level of encoding in order to fully understand and subsequently retrieve the information. Anecdotally, participants only intermittently looked at the cue cards during the execution of the task; as such, individuals with severe episodic memory deficits may have been at a slight disadvantage and may not have taken advantage of the cue cards. It is possible that incorporating errorless learning principles (Clare et al., 2000) in the training design of the TT-NAT may improve the efficacy of the intervention by reducing episodic memory demands. It is important to highlight, however, that despite the link between episodic memory functioning and error monitoring, the TT-NAT intervention still resulted in a higher error detection rate.

Error Correction: A Neuropsychological Enigma

In terms of error correction (i.e., Proportion Detected-Corrected), no differences were observed between the TT-NAT and Standard NAT condition. This finding is not altogether surprising, as participants in both conditions corrected the majority of errors they detected. Although the small difference in correction rates was in the anticipated direction, with TT-NAT participants correcting more errors than Standard NAT participants, ceiling effects may have prevented a more comprehensive evaluation of the finding. However, the results do provide additional support for the assertion that error correction may not be the central point of concern for individuals diagnosed with dementia (Bettcher et al., 2008); the source of their difficulty may disproportionately lie within the domain of detecting and evaluating action errors.

Notably, Proportion Detected-Corrected was not related to any of the neuropsychological tests used in the study for the TT-NAT condition, and was only marginally related to a measure of general cognitive functioning (MMSE) for the Standard NAT condition. Previous work from our lab demonstrated a modest correlation between measures of visuoconstructional ability (Clock Drawing Total Errors; $r_s = -.28$) and error correction in the Standard NAT; however, this explained only a small proportion of the variance for Proportion Detected-Corrected (11%; Bettcher et al., 2008). Furthermore, additional steps were taken in the current study to reduce the effects of collinearity and control for general cognitive functioning (MMSE). As such, the present study represents a more rigorous approach to evaluating the neuropsychological foundations of error monitoring processes in dementia. Considering the lack of significant relations between error correction and tests of specific neuropsychological processes, it is worth evaluating why this construct remains enigmatic.

One appreciable reason for this finding (or lack thereof) is that the cognitive protocol used in the study may not have adequately addressed the neuropsychological processes involved in error correction. Although we attempted to incorporate commonly utilized measures of executive functions, language, and memory for the current study, a comprehensive neuropsychological evaluation was not employed. As a result, measures not included in the current study may have been more optimal predictors of action-error correction, including indices of post-error slowing (Reason, 1990) and complex executive functions. For example, once an individual detects an error, they must determine how to resolve the issue in the form of a correction. This likely entails problem solving, inhibition, sustained attention, and abstraction abilities that were underrepresented in the study's neuropsychological protocol. Furthermore, the neuropsychological evaluation of everyday action knowledge is understudied (Funnell, 2001). There are very few standardized instruments available to evaluate semantic knowledge and no standardized, published, and validated measures of everyday action knowledge; thus, language measures were used to assess language functioning more generally in the present study. It is important to note that recent studies suggest that semantic knowledge for objects or everyday action may be represented or stored differently than knowledge for other domains (e.g., animals, foods, etc.; Funnell, 2001; Patterson, Nestor, & Rogers, 2007). As such, error correction may be more strongly related to action-specific semantic measures.

Implications for Rehabilitation

The implications for employing the TT-NAT in a rehabilitation setting are heartening and point to a more evidence-based approached to everyday action treatment in dementia. For older adults with specific interests (e.g., cooking) or a daily routine (e.g., doing laundry), this intervention offers a potentially viable means of enhancing their autonomy as well as encouraging their engagement in previously enjoyed tasks. We acknowledge that the intervention likely must be tailored to each task and should be performed just prior to when the task is performed. Therefore, it is important to address the feasibility of this intervention for family training, with the ultimate goal being to apply these techniques in the home. A large-scale effectiveness study should be conducted to properly evaluate this question, as changes in health care and insurance coverage necessitate both feasibility and time efficiency in disseminating intervention techniques to families. Results from the current study suggest that this is not a cumbersome intervention. The training sessions required only approximately 5–10 min prior to each task and were inexpensive to conduct: They only necessitated task pictures (taken from a home camera) and a brief video. The adaptability of the intervention to more technologically savvy older adults was not addressed in the current study. It remains to be seen whether similar presentation of the intervention on a smartphone would be equally efficacious, but is an important consideration for the aging baby-boomer generation. In sum, the TT-NAT demonstrates considerable promise as a tool for ameliorating everyday monitoring problems in a rehabilitation context.

Future Directions

Careful consideration of the results and limitations of the current study point to two primary issues that should be addressed in future studies: generalizability and maintenance of effects. Results from the current study suggest a need to evaluate the generalizability of the TT-NAT intervention. The current study demonstrated superior error detection rates when participants performed the same tasks on which they were trained in the laboratory. The results do not address whether the training principles translate to the home environment and whether training on one task can be transferred to a similar task (e.g., making coffee and, subsequently, making tea). This would be important information in determining the functional utility and applicability of the training.

Future studies should address the maintenance of task training effects over time. In the current study, the training session and task execution occurred back to back to evaluate error monitoring performance in an optimal setting. Determining the amount of time that lapses before a patient needs a "booster" training, or to identify whether patients need continual exposure to the training sessions, can only be adequately answered in future longitudinal studies.

Conclusion

Improving everyday action in patients' lives is a complex and, at times, nebulous goal, as it frequently involves factors that are difficult to capture in research, namely, individualization and ecological validity. The current study purported to address error monitoring impairments in dementia using a naturalistic, theory-based intervention for planning deficits. Results suggest that the Task-Training Naturalistic Action Test is associated with lower total errors and higher error detection rates than the Standard NAT condition. These findings have considerable implications for rehabilitation and caregiver training, as patients may benefit from targeted action interventions that address mild to moderate degradations in task knowledge.

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