Object-Based Practice Effects

Recover the Graphic Object Concept in Alzheimer's Dementia

Hind S. Bechari-Martin^a and Christiane Lange-Küttner^b

^a University College London, National Health Service (NHS) Improving Access to Psychological Therapies (IAPT) Service, London, UK

^b University of Bremen, Dept. of Psychology, Bremen, Germany

This manuscript has been accepted on the 5th October 2021 ©American Psychological Association, 2021. This paper is not the copy of record and may not exactly replicate the authoritative document that will be published in the APA journal *Psychology of Aesthetics, Creativity, and the Arts*. The final article will be available upon publication.

Please cite as follows: Bechari-Martin, H. & Lange-Küttner, C. (in press). Object-based practice effects recover the graphic object concept in Alzheimer's dementia. *Psychology of Aesthetics, Creativity and the Arts*, <https://doi.org/10.1037/aca0000452>

Author Note

We have no conflict of interest to declare. The study was carried out while both authors were at the London Metropolitan University, UK. The first author was awarded the Tom Walsh prize for the best research project of the year. The research was virtually presented as a poster at the Annual Convention of the American Psychological Association 2020 in Washington, DC, USA. We thank Silvana Simonovich, Giovanna Pacco and Elisa de Morpurgo from *Associazione Goffredo de Banfield* and Tiziana Semi from the nursery home *Ad Majores* for their essential support prior to and during the data collection. The corresponding author is c.langekuettner@uni-bremen.de

Abstract

The current study tested object drawing, object naming and object-in-scene perception. We tested older people with Alzheimer's dementia (AD) because their object drawings have often lost their typical contours. We investigated whether intensive practice could improve or recover deteriorated graphic object representations in three tasks, object naming, object-in-scene and object drawing. Ten older participants with AD and ten healthy controls practiced for five consecutive days always involving the same ten objects (item-based learning). Patients with AD closed the gap to healthy controls as reaction time decreased and accuracy increased. Performance level and task difficulty was dependent on age, education and length of retirement duration, but interactions between practice and task difficulty were not. In accuracy, the group difference disappeared earlier in object naming < object-in-scene < object drawing. During the five days of practice, lost graphic object concepts could re-emerge. Multiple regressions testing synergistic effects between tasks showed that rapid object-in-scene judgment and drawing time relatively consistently and reliably predicted object drawing accuracy. However, when testing day-to-day progress of the drawing score, after the first repetition, only the object drawing score of the previous session significantly predicted the graphic object representation. Thus, while perceptual judgment of an object in an appropriate visual scene predicts object drawing - just as in previous research using the Witkin Embedded Figures Test – the fine motor skills involved in visually realistic drawing are likely to be the most important factor to generate a recognizable graphic object representation.

242 words

Keywords: graphic object representation; object naming; object-in-scene perception; object-based learning; Alzheimer's dementia

Object-Based Practice Effects

Recover the Graphic Object Concept in Dementia

Aging, mild cognitive impairment and dementia is currently assessed by the Clock Drawing Test which, besides the age factor, shows a strong influence of education (Mazancova et al., 2016; Talwar et al., 2019). Indeed, creating pictures needs education and has been a human endeavor since ancient times as we know for sure from cave paintings which have survived until today (Anati, 2002; Milbrath, 2010). Most of these paintings involve the silhouette drawings that are mentioned in Plato's ancient Greek text of the cave allegory, for instance, a cave painting of animals including a dinosaur was dated 1000 BC but is likely to be much more ancient (Lange-Küttner & Green, 2007, p. 260, Fig. 1). In the narrative of the cave allegory, philosophers are arguing whether the shadow reflections of objects on the cave wall can tell us more than the real objects outside the cave (Plato, 380BC/2013).

In the current study, we show that adults with Alzheimer's dementia (AD) who suffer from various visual and spatial dysfunctions and who have lost access to their object representations can learn again to draw meaningful object shapes. Drawing in dementia often lacks attention to detail and spatial relationships which nevertheless may still allow to create aesthetically pleasing non-figurative paintings (B. L. Miller & Hou, 2004). Patients with semantic dementia lose not only graphic details in their drawings, but also the typical contour outline of the object shape, so that the object itself is unrecognizable (Bozeat, Lambon-Ralph, et al., 2003). While patients with dementia can often copy from a model, the drawing schema is completely lost after a very short delay duration between seeing a model and drawing it (Ferber et al., 2007; Patterson & Erzinçlioğlu, 2008). We practiced with people with Alzheimer's dementia (AD) to draw shapes of a limited set of objects, and we supported this practice with other visual tasks using the same objects in two other task contexts, namely semantic memory (object naming) and perception of object-in-scenes.

Our new hypothesis was that using the identical objects in different task contexts should create a synergistic effect that would inform the creation or restoration of a graphic object concept. Here we first describe step-by-step how a graphic, visually realistic object representation is created, second, we introduce previous research on object identification and instance-based learning, and in a third section, we describe some of the problems that people with dementia face, particularly in identifying visual scenes. Finally, we refer to previous research that also investigated more general practice effects in older populations to estimate the likelihood of success when running practice sessions for five consecutive days on object naming, object-in-scene and drawing tasks. However, we found that none of the previous studies had used a repeated measurement design with always the

identical objects across experimental tasks in order to increase object familiarity and to support the creation or rehabilitation of a graphic object representation.

Silhouette Drawings

In one cave painting, the silhouette of a dinosaur could be found along with depth cues such as object shape rotation, unfolding of objects' sides in space, and diminishing size with distance (Anati, 2002; Lange-Küttner & Green, 2007) showing that silhouette cave paintings are much older than Plato's philosophical considerations about appearance and reality. It is likely that the creators of these cave paintings were adults. Some theorists have claimed that phylogenetic development is mirrored in ontogenetic development (Fink, 1982), but nowadays children do not start drawing such silhouette object shapes from the beginning. Instead, they begin their drawing development with scribbling, leaving traces of their actions (e.g. Jolley, 2010; Luquet, 1927/2001). Thus, drawing as an activity is not embedded in humans as an innate ability which unfolds as soon as an infant takes a pencil or crayon. Instead, it takes cognitive effort and several months of practice until young children are able to draw an apparently simple closed contour of a shape (Morra & Panesi, 2017; Pinto et al., 2011). This closed contour of a recognizable shape is called a template or a schema when researchers want to stress that a drawing is not created anew each time it is drawn, or it is called a graphic object representation when the many dimensions such as size, shape, or color of an object are considered.

Once shape drawing is mastered, young children use quickly drawn quasi-geometric angular and round shapes (Lange-Küttner, 1998) that are combined into aggregates using lines as connections or extensions (Willats, 2005). This poses a problem especially when drawing objects that are not inherently geometric such as animate objects like animals and human beings (Lange-Küttner, 2011). With the onset of school, gradually these picture primitives become integrated into a figure with a smooth and varied, visually realistic, typical object contour (Deręowski & Dziurawiec, 1996; Lange-Küttner et al., 2002). Some children can also draw visually realistic silhouettes when they are younger, but these lack internal detail (Reith, 1988). Integration of detail can occur because with the onset of school, handwriting requires better fine motor skills which then translates into drawing (Tabatabaey-Mashadi et al., 2015).

Silhouette drawings are especially hard to identify when no internal detail is provided (Lawson, 1999). In models of computerized object recognition, the same problem of a visually realistic silhouette occurs when concepts of figure models consist of cylindrical shapes (Marr & Nishihara, 1978). While the cylinders can be stretched in any extension and create approximations of recognizable objects such as giraffes or apes, the visually realistic contour is lacking. This problem

can be partly solved by the invention of a set of more varied geometric primitives that allowed combinations into objects with a more visually realistic contour (Biederman, 1990).

Thus, there are two steps when creating a graphic object representation, first, the drawing of closed shapes, and second, the integration of parts into an overall visually realistic silhouette. Drawing shows little deterioration in professional graphic designers over the life-span (Lindenberger et al., 2008). In a study with a group of six 64- to 81-year-old and another group of six 22- to 24-year-old graphic designers and control groups, the older graphic professionals fared significantly better than their age-matched peers on the Torrance Visual Creativity Test, while this was not the case in the younger age groups. This test provides just two lines that need to be completed to an object. However, drawing visually realistic contours can be particularly challenging for patients with Alzheimer's dementia (AD) (Bonoti et al., 2014): when ten 10 patients with AD and 10 adult controls as well as of 40 4-, 6-, 8-, and 10-years old children were asked to draw objects from memory, only the drawing scores of the older children were similar to those obtained by adult control group. Patients with AD showed significantly higher error levels than the 4-year-old children.

In particular, patients with AD show spatial distortions of shapes, gross simplifications with lack of detail and errors in 3D perspective drawing, especially in complex drawing tasks, while patients with other forms of dementia can show different kinds of errors (Trojano & Gainotti, 2016). For instance, the main problem for patients with semantic dementia when drawing from memory is that they would need to retrieve a graphic template, while copying from a model is intact (Bozeat, Lambon-Ralph, et al., 2003). Patterson and Erzinçlioğlu (2008) give several examples from three patients with semantic dementia who could produce accurate object drawings, for instance, of a cow, a frog, a bike, a piano, from black-and-white drawings of the Snodgrass and Vanderwart (1980) database of images. The examples appear to show that the more accurate the drawing from the model, the more recognizable was also the drawing from memory, indicating an underlying ability that is severely constrained by limited working memory. However, Patterson and Erzinçlioğlu also show that very characteristic features are lost such as the tails of a kangaroo and a squirrel, the hump of a camel, the grip of a saw, and the brush of toothbrush. Thus, from this evidence, it was not clear whether patients with AD would be able to improve during repeated practice sessions.

Practice and Object-based Learning

Practice to draw and object-based learning in adults has been discussed by Cohn (2012). He suggested a cognitive drawing model that has eye-hand control as the very basis for creating a graphic vocabulary. This graphic lexicon of object schemata is then controlled by a graphical syntax that specifies a production script that follows combinatorial principles for drawing.

The protracted developmental trajectory in the early school years shows that the integration of graphic detail into a visually realistic contour of a graphic object is an effortful process. There are not many studies where pre-school children achieved an ideal level of such visual realism purely by practice. Gifted children need and show intense engagement with the drawing material and model and a 'rage to master' (Milbrath, 1998; von Károlyi & Winner, 2005; Winner & Drake, 2013). Also some gifted children with autism can show obsessive practice and can achieve self-taught 'savant' 'graphic fluency', that is, they can sketch visually realistic from life like adult artists (Happé & Frith, 2010). Both these well-practiced children, with and without autism, show great attention to detail if they draw visually realistically (Drake et al., 2010; Drake & Winner, 2011). In contrast, typically developing children lose track of details during practice until they are about 11 years old and become more creative in their graphic production (Lange-Küttner et al., 2014): When asked to repeat a human figure drawing several times, 11-year-olds depict a new person on each occasion and thus do not lose out on visual details, while younger children try to repeat exactly the same drawing as before but gradually reduce their drawing to a sort of template.

Single objects are the sole visual focus of young children, while their mothers monitor the whole array of objects (L. B. Smith et al., 2011). Moreover, young children can recognize rotated single objects such as a cube (Lütke & Lange-Küttner, 2015), while with age, they also become accurate in identifying well-designed rotated cube aggregates (Lütke & Lange-Küttner, 2021).¹ Some researchers assume that this process takes years because mental rotation would require spatial concepts, in particular the concept of three dimensions (Hoyek et al., 2012). Still, first, the studies of Lütke and Lange-Küttner showed that the cubes' design features and color are important for children's mental rotation. Especially object edges and contours play an important role in mental rotation (Tzuriel & Egozi, 2010). Second, with practice, children can achieve adult performance levels in object rotation tasks (Kail & Park, 1990).

Theoretically, if spatial concept development is involved, mental rotation of an object could be transferred to novel objects like in classification. Once the principle of categorizing objects by extracting one dimension that unites all exemplars into one class is understood, the actual identity of the item becomes irrelevant, so apples and pears are both the same type of object, fruit. Thus,

¹ Mental rotation involves being able to identify an object when shown from another visual angle. There is usually one target object that is compared to the views of a second, or several other rotated objects, built in slightly different ways, or presented as mirror images. The comparison object needs to be identified as same or different to the target (match-to-sample).

the extraction or abstraction of a single feature or property is a process that could be used on any object (transfer) and allows to accept selected items into an object category.

This transfer to novel objects indeed occurred in adult Harvard University students after practice with 2,394 trials on 21 consecutive days (Wright et al., 2008). In normally aging populations, only up to a third of the differences in mental rotation ability between people over a life-span from 20 to 80 are explained by age (Salthouse, 1991). However, Kail and Park (1990) showed that 11-year-old children could not transfer their acquired mental rotation expertise to other objects, even after practice with 3,168 trials in 11 sessions, but their trained mental rotation ability was specific to the particular object that they had seen during practice. This fixation on one object as in the previously mentioned study of L. B. Smith et al. (2011) is called instance-based learning. It shows that learning an object representation can be very item-specific especially in children and presumably also in individuals with limited cognitive resources like people with dementia.

To the best of our knowledge, there is only one case study, where a patient with severe semantic dementia could recover functions of objects after practice (Bozeat et al., 2004). In this study, the use of some objects was demonstrated and the patient was asked to copy the movement made by the examiner. During the repeated practice sessions, improvement was achieved, but gains were higher for objects with a demonstration than those without, especially for holding and orienting the objects. The more dynamic aspect of moving an object was not learned without demonstration. This case study of semantic dementia showed that the representation of the meaning and function of an object that appears to be lost can be recovered with practice. In a semantic combined classification and recognition task of words for living and non-living things, both older adults with and without dementia showed repetition-related increases in word processing efficiency as indicated by a reduction in brain activity (Lustig & Buckner, 2004). However, problems in Alzheimer dementia in the visual domain can be more widespread than in semantic dementia.

Visual Cognition in Dementia

Dementia is an umbrella term for a set of chronic and acquired neurodegenerative disorders (American Psychiatric Association, 2013). It is characterized by the progressive deterioration of cognitive functions accompanied by alterations in behavior, personality, and affectivity. Currently, worldwide about 5% of the population over 65 is affected by dementia, with the percentage increasing to 30% for the over 85 years old (World Health Organization, 2017). Alzheimer's disease (AD) is the most common type of dementia with around 60% of dementia cases, while vascular dementia (VaD) makes up around 20% (Jørgensen et al., 2020). Both types of dementia can produce some similar symptoms, but the pathological mechanisms are very different. While VaD is caused by

a reduced blood supply to the brain due to narrowed blood vessels, AD is characterized by synapse loss, neuronal atrophy, and an abnormal accumulation of amyloid beta ($A\beta$) protein resulting in senile plaques which disrupt neuronal signaling and can cause inflammation (Jørgensen et al., 2020).

A decrease in memory is widely considered as the most evident phenomenon characterizing AD (Charles & Hillis, 2005). Among the different types of memory, the most affected appear to be event-based episodic memory and short-term memory (Hulme et al., 1993; Irish et al., 2013). Although debated, semantic memory also appears to be compromised in AD (Moore et al., 2004; Ralph, 2001). Semantic memory is important as it includes the knowledge of the facts, meanings, and concepts concerning objects in the external world. The neural damage in semantic dementia appears to vary, though, in different brain regions depending on the type of knowledge, but all areas are left lateralized (Grossman et al., 2003; see also Hurley et al., 2015). Multiple other verbal and behavioral deficits can occur such as reduced expressive and receptive vocabulary, anomia as well as surface dyslexia and dysgraphia (Yang et al., 2015). Responsible for the multiple deficits would be a disconnection syndrome in the brain network which disrupts the multi-sensory and multi-modal information integration that is needed for episodic memory (Irish, 2016). This network consists of the medial prefrontal cortex, the angular gyrus, the medio-temporal lobe and other posterior regions including the cingulate cortices, precuneus and cerebellum. The anterior temporal lobe serves as a hub for the network and reduced input from visual regions was found to be leading to atrophy in the ventral what-system for object representations (Guo et al., 2013).

These multiple problems suggest that also the perception of an object in an environment (scene perception) (Rensink, 2000) would be a problem for patients with AD. Scene perception and memory involve both context as well as binding of objects to locations in the scene (Hollingworth, 2009). The brain substrate of scene perception is located in the right lateral occipital lobe (Dilks et al., 2013). Patients with AD are at chance when it comes to recognizing portrait paintings, landscape paintings, and landscape photographs they had seen two weeks before (Graham et al., 2013). The memory for the environment itself is located in the anterior hippocampus, a subcortical area (Zeidman & Maguire, 2016). In a pairwise comparison of natural and urban scenes, Patients with AD were at chance when identifying natural visual scenes containing no objects such as cars, trams or people (Lenoble et al., 2015). This suggests that they are particularly dependent on objects and not sensitive towards the visual global properties of scenes such as a horizon (spatial axis). Moreover, patients with AD's visual attention significantly more often gravitates towards incongruent matches between objects and scenes than in age-matched controls when given a view-specific instruction to focus on the background, but not with an object-specific instruction or in a free viewing condition (Lenoble et al., 2018). When visual scene perception in AD deteriorates, patients often find themselves unable

to orient even in familiar surroundings, thus, scene perception seems to be a key visual cognition domain, yet such studies with patients with AD appear to be comparably rare.

There are different classes of relations between an object and a visual scene: probability refers to whether an object belongs or does not belong in an environment, while familiar size refers to whether an object has a realistic, proportionate size within the environment (Biederman et al., 1982). Visually realistic size in a spatial context is an object feature which, for instance, children only very slowly achieve in their graphic representations (Lange-Küttner, 1997, 2004, 2009). Patients with AD tend to focus more on incongruent objects in scenes (Lenoble et al., 2018), but also normally aging adults over 75 found objects harder to categorize when they were located in an incongruous spatial context (Rémy et al., 2013).

The Current Study

We did not use a drawing task to make a differentiated medical diagnosis of a particular type of dementia (Trojano & Gainotti, 2016). Instead, the rationale of the current study was that patients with AD would significantly benefit when the same objects are presented in object-naming and object-definition (SEM), probability and familiar-size in scenes (SP); and image-copying and drawing from memory (DWG) because experience with the same objects across these tasks would familiarize and strengthen the object concept. To the best of our knowledge at the time of writing, no studies have directly compared semantic memory, scene perception and drawing, nor was the same set of stimulus items used across different tasks in any training study with patients with AD.

In the current study, firstly, we adopted the identical items and categories of stimuli/objects across different cognitive tasks. Our method was intended to foster implicit learning across different cognitive domains while consolidating and improving the knowledge of specific objects, based on the Hebbian learning theory (Hebb, 2002) and the principle of unconscious associative, implicit learning (Verguts & Notebaert, 2008). The effortless knowledge formation principle behind implicit learning relieves dementia patients from the requirement of high levels of attention occurring in explicit learning (Reber et al., 1999). In this way, we aimed to optimize object knowledge with an experience of the same objects in different task contexts so that it could create or repair object concepts (Bozeat, Lambon-Ralph, et al., 2003; Bozeat et al., 2004).

Secondly, so to take advantage of the practice effect (Benedict & Zgaljardic, 1998; Duff et al., 2007), we tested participants each day, five days in one week to provide an intensive practice opportunity. A very recent review of 47 practice studies with patients with dementia, or at risk for dementia, by Carrion et al. (2018) showed mixed results. General cognition measured by the Mini Mental State Exam (MMSE) and the Alzheimer's Disease Assessment Scale-Cognitive Sub-scale (ADAS-Cog)

improved in almost half the studies. An unexplained effect was that often only one ability amongst many others improved.

The length of training did not matter as both a 2-year training as well as a 2-week intervention improved performance. Carrion et al. (2018) found four recent studies with a five-day-a-week practice (Bergamaschi et al., 2013; Kim et al., 2016; Kolanowski et al., 2016; Venturelli et al., 2016). Bergamaschi et al. (2013) found significant increases in verbal fluency and memory, Kim and Venturelli (Kim et al., 2016; Venturelli et al., 2016) found no significant improvements, while Kolanowski et al. (2016) found improved executive function in a Clock Drawing test, but none in attention and memory. This success rate is in line with other practice regimes which were effective in only half of the studies.

Vision-based speed of processing practice (VSOP, selective and divided visual attention) versus mental leisure activity (MLA, crossword, sudoku and solitaire) showed that the vision-based tasks reduced response times more than leisure activities and increased working memory in older adults with mild cognitive impairment (F. Lin et al., 2016). Moreover, VSOP practice improved connection strength (composite score) in the central executive neural network.

Thus, we expected that on the basis of instance-based learning theory, using the same items in different task contexts on five consecutive days would improve the performance of the AD group (here: object-based learning). We selected objects that belonged to categories of daily life as items in the experimental tasks. In addition to objects, faces of famous people were included as stimuli because individuals living with AD appear to struggle with visual recognition of both objects and faces (Mendez et al., 1990). We used an extended within-participants design with practice on five consecutive days.

Method

We chose to intensively test a smaller sample for five consecutive days with three tasks each involving ten objects, creating in total 300 data points per person (see section Data generation for how these were averaged). We measured the covariates age in years, years of education, and years of retirement. We first analyzed the practice effects for each type of task (object naming, object-in-scene, object drawing) in a mixed multivariate analysis of variance. We then analyzed whether there is a synergistic, supportive effect of object naming and object-in-scene on object drawing because in the daily sessions, the former two were always given before the object drawing: first, we were running correlations per session, and second, we were determining the best predictor for object drawing per day with multiple regressions. The multiple regressions also included the drawing of the previous day as a predictor in order to determine a domain-specific practice effect.

Participants

Based on previous research (e.g. Bonoti et al., 2014; Bozeat, Ralph, et al., 2003; Lindenberger et al., 2008), 20 Italian individuals were recruited, 10 healthy older adults and 10 patients with Alzheimer's dementia. All participants had normal or corrected-to-normal vision and hearing.

All participants received the Italian version of the MMSE (Magni et al., 1996). The lower the score, the higher the likelihood of dementia. Participants with scores between 13 and 17 indicating moderate dementia and between 18 and 23 indicating mild dementia were included in the AD group. Scores above 24 were required to be included in the healthy control group. **Table 1** shows that the group difference on the MMSE was highly significant.

Because participants' years of education could not always be exactly reconstructed, and schooling was not always completed, a categorical variable was created that was a compromise between school level and years of education (Contador et al., 2017). The four durations of school education were 0-4 years, 5-7 years, 8-12 years and 13-17 years. In the control group there were 4 participants with 8-12 years of education and 6 participants with 13-17 years of education. In contrast, in the AD group, there was 1 participant with 0-4 years of education, 5 participants with 5-7 years of education, 3 participants with 8-12 years of education and 1 participant with 13-17 years of education. The group of patients with dementia was significantly less educated, $\chi^2(3, 20) = 9.71, p = .021$, $\phi = .70$, and also when tested with a t-test for independent samples, see **Table 1**. Because the duration of education clearly plays a role in dementia diagnosis in old age (Contador et al., 2017; O'Shea et al., 2018; Then et al., 2016), we included years of education and also years of retirement in the statistical analyses.

Material and Apparatus

The EPrime 2.0 experiment is deposited on <https://osf.io/u289Ee/>. A touchscreen Toshiba Portege M780-10V with a 12.1" screen resolution was used to present the experiment to the participants. Blank sheets of A4 paper were used for the drawing task. The experiment was programmed with E-prime and contained a total of six tasks, two for each of the three domains: Semantic Memory (SEM), Scene Perception (SP) and Drawing (DWG). Latencies, and in the drawing task, time to complete, were measured because speed is a factor that deteriorates with old age (Salthouse, 1996).

Participants were not given feedback. A total of ten objects from five categories were used across tasks. Two black-and-white drawings of famous people (Queen Elisabeth II, Pope John Paul II) were selected from free Google Images. The remaining eight pictures of objects were selected from the black-and-white drawings of the Snodgrass and Vanderwart (1980) picture set where norms were available. Lower scores represent higher rater agreement, with a value of zero represents a perfect

agreement between raters. We used two objects for each category (name agreement/familiarity/-visual complexity score): Two animals (penguin 0.38/1.70/2.82, horse 0.00/2.55/3.80), two household objects (table lamp 0.44/4.20/1.85, toothbrush 0.16/4.62/2.42), two fruits (banana 0.00/3.65/1.32, strawberry 0.17/3.20/3.38), two inanimate objects (car 1.08/4.70/4.05, watering can 2.03/2.72/2.78). With the exception of the two inanimate objects, naming agreement was very high. Italian picture norms for naming are not available for all of these eight objects (Barca et al., 2002; Dell’Acqua et al., 2000). According to the most compatible list of Dell’Acqua et al., the Italian naming agreements scores are penguin 1.26, horse 2.94, table lamp 2.19, banana 1.68, strawberry 1.56, car 2.60, with norms unavailable for pictures of the toothbrush and watering can.

The order of each item was randomized within each task for each session. There is evidence that naming of objects in AD patients is influenced by the factors age of acquisition (AoA), name agreement and category, with living objects being easier than non-living objects (Silveri et al., 2002). However, the latter seems to be gender-specific, with women being more efficient for living things and men for artefacts (Barbarotto et al., 2002). In the current study, we averaged performance across the ten objects and did not analyze object categories. The hypothesis of our study was that using the same objects in different task contexts would improve the gain of function for object representations during practice over several consecutive days as, for instance, in verbal learning (O’Shea et al., 2018).

Semantic Memory (SEM). There were two exercises within the SEM domain, namely, object-naming and object-definition. In the naming task, participants were shown one image at a time and asked to name it by choosing one of four rectangular buttons on the screen itself. **Figure 1A** shows as an example a picture of a penguin that could be named as such, or as a lion, an eagle or a hammer. The font was Courier New 30 Bold. The object-definition task consisted of asking participants what the object was and what it was used for.

Scene Perception (SP). The visual perception task involved colored images which were created with Adobe Photoshop CC 2017, controlled for color balance, luminance, and contrast, see the complete sets in the supplementary file. Each of the ten objects was shown embedded within two different backgrounds which were presented side by side, see **Figure 1B**. Only one of the backgrounds was the correct context for the object. Participants were asked to touch what they believed to be the correct picture.

We devised two versions of the scene perception task, namely probability SP and familiar-size SP. The probability SP task involved an object in a probable and realistic background versus an impossible context which violated expectations. In the example in **Figure 1B**, the snowy landscape

on the right-hand side is the correct context for the penguin, and not the living room. The familiar-size SP task showed two possible scenes at a time, but in one scene, the size of the object was out of proportion.

Drawing (DWG). We showed the drawing model and instructions on the screen so that the drawing time could be measured, see **Figure 1C**. The drawing itself was completed with pen and paper. Once a drawing was completed, participants were asked to touch the screen to proceed to the next, which triggered the offset of the instruction, measured drawing completion time and released the next drawing model. There also were two tasks, image-copying DWG and memory DWG.

To relieve participants with dementia, the ten objects were divided in two groups of fives so that in each type of drawing task, there was one object of each category. The image-copying DWG task consisted of participants being asked to copy the drawing model they could see on the screen. In the memory DWG condition, the computer just showed a screen with an instruction on what to draw.

Procedure

The study was carried out in Trieste, Italy, which has a large population showing longevity (Tettamanti & Marcon, 2018). In Italy, a National Health System exists with autonomous local health authorities (LHAs). Participants were recruited via the charity organization *Goffredo de Banfield* www.debanfield.it whose mission is to look after patients with AD or other types of dementia in their own homes. For the current study, with their consent, only participants with an Alzheimer's type of dementia were selected by the charity based on their medical record. The AD group in the current study was, with the exception of one individual who was 69 years old, above 70 years of age (75, 77, 77, 84, 85, 85, 87, 89, 90 years), thus, the diagnosis of Alzheimer's dementia was less contentious than if participants were in their sixties (Breton et al., 2019; Ciesielska et al., 2016).

The research was conducted ethically in accordance with the [World Medical Association Declaration of Helsinki](http://www.wma.net/e/declaration/). Ethics permission was obtained from the Ethics Board of a UK Psychology Department which follows the Code of Human Research Ethics of the British Psychological Society <https://www.bps.org.uk/news-and-policy/bps-code-human-research-ethics-2nd-edition-2014>. In addition, the Italian Ethical code for research in Psychology of the Italian Psychological Association was followed, <http://www.aipass.org/node/11560>. Moreover, the study was compliant with the guidelines of the Italian Ethics Commission for Bioethical Research in the Social Sciences https://www.cnr.it/sites/default/files/public/media/doc_istituzionali/ethics/Carta-dei-principi-per-la-ricerca-nelle-scienze-sociali-e-umane-4-5-2017.pdf.

All participants were tested in their own home except for three participants with AD who were care home residents and tested there individually in their rooms. In the first session, the presence of a

caregiver (if in place) was mandatory. Participants took part in five sessions, one on each consecutive working day for one week. Briefing-consent forms and demographic data were collected from the participants and their caregivers. Dementia participants who consented themselves were asked at the beginning of each session if they remembered the researcher, the experiment and their previous participation agreement. In case they did not, briefing and consent were repeated. Each session lasted approximately one hour.

We placed the touch screen laptop computer in front of the participants so that they could comfortably reach for the screen. Participants were asked to read out aloud the instructions presented on the screen and if they had any questions these would be addressed before the start of the first trial. Participants were encouraged to take breaks in between task blocks, but not during a block of trials. Once the object naming and object-in-scene tasks were completed, we positioned the computer only so much further away from the participant as to allow space for a blank piece of paper to be placed in front of them for the drawings.

Data Generation. E-Prime recorded accuracy and reaction times as well as drawing completion times, respectively. Reaction times (RT) for correct and incorrect responses were separate variables. There were in total 300 data points per person (10 items x 3 tasks (10 SM + 10 SP + 10 DWG) = 30 data points plus response timings = 60 data points x 5 days = 300 data points per person) equivalent to 6,000 data points in total for twenty participants. For semantic memory and scene perception, we report reaction times only for accurate responses. For drawing, we report completion times. We averaged scores across objects per task per day, resulting in 3 tasks x 2 (accuracy/timings) x 5 days = 30 dependent variables.

For the drawings, a scale was designed to mark each drawing following previous research (e.g. Aprahamian et al., 2009; Bozeat, Lambon-Ralph, et al., 2003; Karmiloff-Smith, 1990; Kitabayashi et al., 2001; Patterson & Erzinçlioğlu, 2008). Drawings were scored by the following four criteria (1) **Visual Realism** (answers the general question “Does this look like what it is supposed to be?”): 1 point if it does; 0.5 if the drawing resembles somewhat the object but not fully; 0 if not recognizable. (2) **Proportions** (answers the question “Do the features included in the drawing represent proportionate sizes?”): 1 if it does; 0 if it does not. (3) **Contoured Shape** (answers the question “Does the shape show lines and curves typical for the object?”): 1 if it does; 0.5 if it partially does; 0 if it does not. (4) **Details** A list of all details was made for each drawing. The points for details were calculated as the percent of the total points, e.g. the horse has ten details such as *tail, ear, leg 1, leg 2* etc., so the percentage for each detail for this particular object was calculated as (‘number of details’*100)/10. A complete list with scoring criteria for each object can be obtained from the first author. An independent judge and the first author separately rated each drawing. Interrater

agreement was 84.8%. Disagreements were discussed and agreed. Means of the four scores, visual realism, proportion, contoured shape and details were summed up resulting in a single accuracy score for each drawing per day.

Results

The data set is deposited in the Open Science Framework (OSF) <https://osf.io/hcvgu/>. The analyses of accuracy and reaction times compared the two groups in the three domains with multivariate analyses of variance in a 3 (tasks: semantics, scene memory and drawing) x 5 (practice in days 1-5) x 2 (control and AD group) design with repeated measures for task and practice. We report the results of the same analysis controlled for age, years of education and years of retirement as covariates in brackets. The covariate-adjusted percentages and response times are quoted following the observed values when statistical effects held. We use the covariates as control because there were significant differences between the two groups.

It could be claimed that controlling for such differences between the two groups removes meaningful variance (G. A. Miller & Chapman, 2001) as according to a very large prospective study, the likelihood of dementia increases with age from a rate of 4.65 per 1,000 at the age of 65-69 to 54.05 per 1,000 at the age of 85-89 (Kukull et al., 2002). However, there was a considerable overlap of age in the two groups in the current study, see **Table 1**, and the t-test was just significant at $p = .047$. Likewise, the likelihood of dementia increases with education of less than 12 years (Kukull et al., 2002). In the current study, although there was a significant difference in terms of education, all participants of this sample had an education of less than 12 years, most likely due to belonging to a cohort who survived World War 2 and thus had only basic emergency schooling thereafter. Hence it could be predicted that the effects of covariates may not become significant but they would still reduce the effect sizes because some variance in the total R was due to these factors.

Beta denotes the observed power. If the Levene's test for equality of variances was significant, the degrees of freedom were adjusted according to Greenhouse-Geisser. **Table 2** shows the longitudinal correlations on consecutive days, with very high and significant correlations for drawing accuracy. The group means per task for accuracy and reaction times are listed in **Tables 3 and 4**.

Accuracy. The analysis of variance of accuracy in per cent revealed a main effect of group as the AD group ($M = 79.6\%/80.9\%$) showed lower overall accuracy relative to the control group, also when controlled for the covariates ($M = 94.3\%/93.0\%$), $F(1, 20) = 35.45$, $p < .001$, $\eta_p^2 = .66$, $\beta = 1.0$ [$F(1, 20) = 10.39$, $p = .006$, $\eta_p^2 = .51$, $\beta = .41$].

There was a significant effect of task, $F(1.15, 20) = 34.64$, $p < .001$, $\eta_p^2 = .66$, $\beta = .1.0$. SEM was the easiest ($M = 97.1\%$) followed by SP ($M = 89.4\%$) and DWG the hardest ($M = 74.3\%$). However, when

the three covariates were added, task difficulty was no longer significant, $F(1.13, 20) = .26, p = .648, \eta_p^2 = .02, \beta = .08$. Not a single significant interaction of task with the covariates was significant, $p_s > .653$, but some variance was absorbed.

The task by group effect was also significant, $F(2, 20) = 10.20, p < .001, \eta_p^2 = .36, \beta = .98$, showing that the AD group performed lower the harder the task (SEM $M = 95.0\%$, SP $M = 84.0\%$, DWG $M = 59.9\%$) while this was less pronounced in the control group (SEM $M = 99.3\%$, SP $M = 94.9\%$, DWG $M = 88.6\%$). However, again control for covariates yielded this effect non-significant, $F(2, 20) = 2.36, p = .111, \eta_p^2 = .14, \beta = .06$.

Thus, while it was clear that the three tasks had different levels of task difficulty, the challenge did not vary between groups when controlled for age, years of education and years of retirement.

There was a significant effect of practice, $F(2.01, 20) = 111.0, p < .001, \eta_p^2 = .86, \beta = .1.0$, with accuracy gradually increasing in the five days (day 1 $M = 78.5\%$, day 2 $M = 84.3\%$, day 3 $M = 87.5\%$, day 4 $M = 90.3\%$, day 5 $M = 94.2\%$). However, when the three covariates were added, the practice effect was no longer significant, $F(1.88, 20) = .22, p = .794, \eta_p^2 = .01, \beta = .08$, showing that although there was not a single significant interaction between practice and the covariates, $p_s > .440$, some variance was absorbed.

However, the two-way interaction of practice by group, $F(4, 20) = 29.9, p < .001, \eta_p^2 = .62, \beta = .1.0$ [$F(4, 20) = 9.67, p < .001, \eta_p^2 = .39, \beta = .99$], and the three-way interaction of task by practice by group, $F(8, 20) = 3.57, p = .001, \eta_p^2 = .17, \beta = .98$ [$F(8, 20) = 4.56, p < .001, \eta_p^2 = .23, \beta = .99$] were significant, without as well as with the covariates. **Figure 2 A-C** shows that the AD group improves in all three types of tasks, and they close the gap with the healthy controls for semantic memory and scene perception, but not for drawing where both groups started lower and improve together. For the post-hoc t-tests for independent samples, the significance level of the p-values was corrected for multiple testing to $.05/15 = .003$. The p-values in **Table 3** show that semantic memory was the easiest to catch up for participants with dementia, with a significant difference to the healthy controls only on the first day. Scene perception was more challenging with a significant difference persisting on the first three days, and drawing needed the most effort, with a significant difference on the first four days.

Response Times. While reaction times in the SEM and SP tasks were response measures, timings in DWG were completion duration times. Therefore, these two types of speed measures were analyzed separately, again without and then with control for age, years of education and years of retirement.

Analysis of variance of semantic memory and object-in-scenes showed a significant main effect for group, $F(1, 20) = 25.13$, $p < .001$, $\eta_p^2 = .58$, $\beta = 1.0$ [$F(1, 20) = 7.91$, $p = .013$, $\eta_p^2 = .34$, $\beta = .75$], as response times of the AD group ($M = 7224/7004$ ms) were slower compared to the control group ($M = 4134/4354$ ms). Thus, the group difference in speed between the AD and the control group was significant also when controlled for the covariates age, years of education and years of retirement. The main effects of the covariates were not significant, $p_s > .664$.

There was a main effect of task, $F(1, 20) = 8.46$, $p < .009$, $\eta_p^2 = .32$, $\beta = .78$ [$F(1, 20) = .119$, $p = .735$, $\eta_p^2 = .01$, $\beta = .06$], as participants could confirm the name of an object faster ($M = 5115$ ms) than its presence in the appropriate spatial context ($M = 6242$ ms). The covariates explained the greater task challenge set by the object-in-scene task. This had been also the case for accuracy.

There was also a main effect of practice, $F(2.30, 20) = 24.41$, $p < .001$, $\eta_p^2 = .58$, $\beta = .1.0$ [$F(2.22, 20) = .317$, $p = .752$, $\eta_p^2 = .02$, $\beta = .10$], as with each day of training, participants became faster (day 1 $M = 7402$ ms, day 2 $M = 6377$ ms, day 3 $M = 5631$ ms, day 4 $M = 5016$ ms, day 5 $M = 3968$ ms). With day 1 as baseline, pairwise comparisons showed that improvements significantly added up, with only the linear polynomial contrast being significant, $F(1, 20) = 57.06$, $p < .001$, $\eta_p^2 = .76$, $\beta = .1.0$. However, the covariates absorbed more variance of this overall training effect than the actual daily practice without reaching significance themselves in interactions, $p_s > .059$.

There was a significant two-way interaction of task by group $F(1, 20) = 13.78$, $p = .002$, $\eta_p^2 = .43$, $\beta = .71$ [$F(1, 20) = 7.16$, $p = .017$, $\eta_p^2 = .32$, $\beta = .71$], and a significant effect of task by practice $F(4, 20) = 2.96$, $p = .025$, $\eta_p^2 = .14$, $\beta = .77$ [$F(4, 20) = 2.46$, $p = .055$, $\eta_p^2 = .14$, $\beta = .67$], see **Figure 2a and 2B**, that were not reduced to complete insignificance when controlled for the covariates. Bonferroni-adjusted post-hoc tests in **Table 4** showed that the task by group interaction occurred because response times for scene perception were slower in the AD group than in the control group and this difference was still present on the fifth day of practice. The task by practice effect was still marginally significant because the faster reaction times of the object naming task still reduced more, by 56.2% from 6524 ms to 3667 ms, than in the object-in-scene task which reduced by only 51.5% from 8280 ms to 4268 ms. The task-specific practice effect did not combine into a three-way interaction with group when controlled with the covariates, $F(4, 20) = 2.84$, $p = .030$, $\eta_p^2 = .14$, $\beta = .75$ [$F(4, 20) = 1.75$, $p = .150$, $\eta_p^2 = .10$, $\beta = .50$], showing that given differences in age and education both AD patients and the control group of adults made efficiency gains with practice.

Analysis of variance of drawing completion times showed no effects of age, years of education, or years of retirement, $p_s > .237$. There were no effects of acceleration or deceleration when drawing, either without or with covariates, $p_s > .298/.561$. Statistically speaking, both groups took about the

same time to complete the drawings, $p = .075/.108$. While **Figure 2C** may give the impression that the AD group took increasingly more time than the control group, boxplots showed larger differences between participants in the AD group than in the control group, yet without outliers, and that the median did not change much in either group. Importantly, in the control group, the standard deviations decreased from 4 min 3188 ms to 2 min 9650 ms, indicating gains in efficiency and routine, but in the AD group the standard deviations increased from 4 min 5543 ms to 4 min 8995 ms, with standard deviations of nearly 5 minutes.

Synergistic effects. In order to analyze whether the three tasks synergistically interacted with each other because they were based on the same objects, we ran correlations (see **Table S1** for correlations for all variables per day). Because we were interested in the synergy between the three tasks on each day, we plotted the significant Pearson correlations (two-tailed), see **Figure 3A-E** with accuracy variables on the left side and reaction times variables on the right side. What became clear was that on day 1, between-task accuracy correlations were important, that is, those participants who had good semantic memory for object names would also be good in identifying the objects in the appropriate spatial context and drawing the object. Moreover, the speed of identifying an object in the appropriate spatial context showed a high correlation with drawing accuracy, not only on day 1, but throughout all of the following days, being the one most reliable, persistent and robust correlation. On day 2, both between-task accuracy and latency correlations were significant. However, in the days that followed, accuracy became less important, while between-task latencies stayed significant.

We then ran a multiple regression for drawing accuracy on each day, with the same variables as predictors for drawing accuracy plus the MMSE, see **Table 5**. On day 1, the multiple R was .87, and the model was significant, $F(1, 20) = 6.56$, $p = .002$. The only significant predictor was drawing completion time, $\beta = .40$, $p = .023$. On day 2, the multiple R was .94, and the model was significant, $F(1, 20) = 16.76$, $p < .001$. Again, drawing completion time was a significant predictor, $\beta = .89$, $p < .001$, but in this first repetition, also object-in-scene reaction times had become a significant predictor, $\beta = -1.27$, $p < .001$. On day 3, the multiple R was .91, and the model was significant, $F(1, 20) = 10.32$, $p < .001$. The same two predictors were significant, drawing completion time, $\beta = .54$, $p = .009$, and object-in-scene reaction times, $\beta = -.87$, $p = .001$. On day 4, the multiple R was .80, the model was still significant, $F(1, 20) = 3.91$, $p = .019$, but only MMSE was marginally significant, $\beta = .50$, $p = .059$. On the final day 5, the multiple R was .86, and the model was significant, $F(1, 20) = 6.05$, $p = .003$. The same two predictors were significant as on days 2 and 3, that is, drawing completion time, $\beta = .45$, $p = .041$, and object-in-scene reaction times, $\beta = -.78$, $p = .027$. These regressions confirmed that taking time (although taking very long did not) and

being able to quickly recognize the appropriate spatial context significantly predicted object drawing accuracy.

Predictive effect for the graphic object representation. The above regressions did not take into account the day-to-day progress that was made when drawing the objects, see some examples in **Figure 4**. Therefore, we ran multiple regressions that included drawing accuracy from the day before, beginning on day 2. Because the covariates were also significantly correlated with drawing accuracy, see **Table S1**, we also included all covariates, see the results in **Table S2**. However, because the results were similar whether or not covariates were included, we herewith report the more simple regression models. The multiple regressions in **Table 6** were all highly significant, $p_s < .001$. The multiple R 's were consistently very high, $R_2 = .97/.97$, $R_3 = .99/.99$, $R_4 = .99/.99$, $R_5 = .97/.98$ showing that the included variables – also without the covariates (values after the forward slash) - explained nearly the total of the shared variance. In comparison with the above regressions, the drawing score of the previous day explained more variance in the later sessions (day2: 3%/3%, day3: 8.8%/11%; day4: 24%/27%; day 5: 13%/14%).

Including the previous day drawing achievement made it absolutely clear that the progress of the graphic concept was domain-specific: Only on day 2 were object-in scene latencies and drawing completion time still significant predictors, on all following days only the drawing score from the session before was significant. The B weights (unstandardized) of the previous-day drawing score were, for day 2 $\beta = .55$, $p = .005$; for day 3 $\beta = .93$, $p < .001$; for day 4 $\beta = .99$, $p < .001$; and for day 5 $\beta = 1.03$, $p < .001$, see **Table 6**.

Discussion

The current research investigated object-based learning in visual cognition in a sample with a group of patients with Alzheimer dementia and a healthy control group. As we know that familiarity is a major factor in implicit learning, we expected that people with AD would have the potential to improve on three visual cognition tasks. We had hypothesized that, theoretically, performance in all three tasks would be sustained by an object representation network in the brain, as object drawing tasks activate object shape representations, semantic memory tasks require remembering object names, and visual scene tasks need to recognize the fit of an object in a spatial context. Our hypothesis was that experiencing the same objects in different task contexts would synergistically strengthen the representation of the same object and thus would enable the recovery of a lost object concept. Performance of people with and without dementia improved in all three domains, and the AD group reliably caught up with the control group on the second day in semantic memory,

on the fourth day in object-in-scene perception and only on the last fifth day in object drawing. Moreover, some intact graphic object concepts emerged during practice.

The training brought about a shift from between-task accuracy towards between-task speed. Speed deteriorates in old age (Salthouse, 1996). In the current study, participants with AD were slower independently of their age, education or length of retirement. Therefore, it is very interesting that the focus in the practice sessions changed from accuracy towards speed, in fact, average reaction times became about twice as fast than in the beginning of the practice course and this was the case in both the AD group and the control group for the semantic memory and the object-in-scene tasks. When drawing, though, patients with AD took more time on each following day while the differences in terms of standard deviations within this group stayed about the same. In contrast, in the control group, drawing completion took about the same time, but the standard deviations reduced during practice showing that the group became more homogeneous in terms of time to complete the drawings. This reduction of standard deviations had also occurred in the semantic memory and the object-in-scene task for both groups. That it did not occur in the AD group when drawing probably suggests that no automatization process (Logan, 1990) occurred but that the additional time taken was required to laboriously create a visually realistic graphic object representation that was not present at the outset of the practice sessions.

The most synergistic, persistent and reliable correlation occurred between drawing accuracy and the ability to rapidly recognize an object in an appropriate context. Semantic object naming was not significant. That patients with AD find scene perception difficult was also found in previous research (Boucart et al., 2014). Initially, the AD group was not only less accurate in the scene perception task, they were also slower than the control group. However, patients with AD showed striking improvements in accuracy and speed in scene memory during the 5-day practice, although the controls became faster too. Object-in-scene perception in relation to drawing accuracy also survived the more rigorous multiple regression which was carried out per practice session. We know that a task such as the Embedded Figures Test (EFT) (Witkin et al., 1971) where it is required to trace an object contour in a noisy visual context, is predictive for object drawing (Drake, 2013; Lange-Küttner & Ebersbach, 2013). However, when day-to-day progress in the graphic object concept was predicted, after the first repetition, only the drawing accuracy score from the previous session was significant. We would explain this result by the difference between perception and action (Goodale & Humphrey, 1998).

That improvement of the graphic drawing concept was best predicted by the drawing accuracy on the previous day speaks to the domain-specificity of such practice. Drawing involves multiple other resources such as fine motor skills (Q. Lin et al., 2015) which are not involved in object naming and

object-in-scene evaluation. It makes sense that especially the drawing of detail and typical object contours requires smooth fine motor skills which were improved due to daily practice in both the AD and the control group. Perception of an object in an appropriate spatial context may predict drawing the contour of the object silhouette, and was still significant on the second day session even when the drawing score of the previous day was included. Thereafter, the drawing had probably gained shape thus making the perceptual identification of an object in a scene less powerful than the sensorimotor skills required to draw the fine detail.

Although drawing requires eye-hand coordination, the current results with a sample of aging participants suggest that the 'hand' is more important than the 'eye' in drawing. Fine motor skills diminish with age (C. D. Smith et al., 1999), especially after the age of 75 when larger deviations from drawing templates can occur even in the absence of any neuropsychological conditions (Hoogendam et al., 2014). However, life-span studies show that learning capabilities stay intact and practice significantly improves fine motor skills (Krampe, 2002; Voelcker-Rehage, 2008).

The comparison between the analysis of the observed values and those adjusted for the covariates age, education and length of retirement revealed some interesting differences. The challenge posed by the task difficulty of the three tasks was the same for the AD and control group when controlled for covariates, but the difference in practice effects of the three tasks occurred independently of such individual differences. Thus, the differences of gain in function acquired in the practice sessions between the three visual tasks still varied when controlled and were robust.

To summarize, drawing was the most challenging of the three tasks. This is consistent with previous research into multiple domains of cognitive practice (Kim et al., 2016). However, while the initial performance level was low, this also allowed for more room for improvement. Drawing accuracy improved considerably during the practice. Moreover, **Figures 4A and 4B** show the drawing template could actually recover and the object concept re-emerged. Previous research had shown that children can regress to earlier stages during repeated drawings (Lange-Küttner et al., 2014), but the present study showed for the first time that also recovery of an apparently lost graphic object concept can occur during practice. Overall, participants with declining abilities benefit and improve the most with practice (O'Shea et al., 2018; Schaie, 1994, p. 311). Also in the current study, the AD group showed constant improvement in the scene perception and drawing tasks. We thus could confirm the three recommendations of Bozeat et al. (2004) that rehabilitation requires rehearsal, frequent practice sessions and familiarity with particular exemplars of objects in order to recover degraded conceptual object knowledge.

There are some limitations due to time and resource constraints. First, we did not test how long the practice effects would last (Bozeat et al., 2004) because of a limited time frame of the study. Bozeat et al. demonstrated robust and lasting gains in a single case study that improved knowledge of object functions which were still significantly above the initial baseline five weeks after practice. Second, neither did we test whether the practice effects would transfer to other objects (Lövdén et al., 2010). Future follow-up studies should require that on each day, some novel objects would need to be drawn, either in a control group, or in addition to the repeatedly drawn objects. Third, it would also be interesting to know whether the EFT would have more predictive power than the object-in-scene perceptual judgments for drawing accuracy because it involves senso-motoric actions.

Our primary theoretical hypothesis was that item-based learning would be likely to occur in patients with AD when using identical objects in several computerized experiments measuring accuracy and response times. Exceeding our expectations, all three different visual cognition tasks produced clear practice gains. Drawing practice on five consecutive days helped to restore some severely degraded visual object representations as shown in two examples the drawing series. Our current task battery explained a very large amount of variance, each task improved during practice, and there was a synergistic effect between the ability to rapidly recognize the appropriate context for an object and object drawing accuracy, but after the first repetition, ongoing improvement was domain-specific, that is, practicing drawing of always-the-same objects predicted drawing objects better.

References

- American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders*. American Psychiatric Publishing.
- Anati, E. (2002). *Höhlenmalerei [Cave paintings]*. Albatros.
- Aprahamian, I., Martinelli, J. E., Neri, A. L., & Yassuda, M. S. (2009). The accuracy of the Clock Drawing Test compared to that of standard screening tests for Alzheimer's disease: results from a study of Brazilian elderly with heterogeneous educational backgrounds. *International Psychogeriatrics*, 22(1), 64-71. <https://doi.org/10.1017/s1041610209991141>
- Barbarotto, R., Laiacona, M., Macchi, V., & Capitani, E. (2002). Picture reality decision, semantic categories and gender: A new set of pictures, with norms and an experimental study. *Neuropsychologia*, 40(10), 1637-1653. [https://doi.org/10.1016/S0028-3932\(02\)00029-5](https://doi.org/10.1016/S0028-3932(02)00029-5)
- Barca, L., Burani, C., & Arduino, L. S. (2002). Word naming times and psycholinguistic norms for Italian nouns. *Behavior Research Methods, Instruments, & Computers*, 34(3), 424-434. <https://doi.org/10.3758/BF03195471>
- Benedict, R. H., & Zgaljardic, D. J. (1998). Practice effects during repeated administrations of memory tests with and without alternate forms. *Journal of Clinical and Experimental Neuropsychology*, 20(3), 339-352. <https://doi.org/10.1076/jcen.20.3.339.822>
- Bergamaschi, S., Arcara, G., Calza, A., Villani, D., Orgeta, V., & Mondini, S. (2013). One-year repeated cycles of cognitive training (CT) for Alzheimer's disease. *Aging Clinical and Experimental Research*, 25(4), 421-426. <https://doi.org/10.1007/s40520-013-0065-2>
- Biederman, I. (1990). Higher-level vision. In D. N. Osherson, S. M. Kosslyn, & J. M. Hollerbach (Eds.), *Visual cognition and action* (Vol. 2, pp. 41-72). MIT Press.
- Biederman, I., Mezzanotte, R. J., & Rabinowitz, J. C. (1982). Scene perception: Detecting and judging objects undergoing relational violations. *Cognitive Psychology*, 14(2), 143-177. [https://doi.org/10.1016/0010-0285\(82\)90007-x](https://doi.org/10.1016/0010-0285(82)90007-x)
- Bonoti, F., Tzouvaleka, E., Bonotis, K., & Vlachos, F. (2014). Do patients with Alzheimer's disease draw like young children? An exploratory study. *Journal of Alzheimer's Disease*, 43(4), 1285-1292. <https://doi.org/10.3233/jad-140528>
- Boucart, M., Calais, G., Lenoble, Q., Moroni, C., & Pasquier, F. (2014). Differential processing of natural scenes in posterior cortical atrophy and in Alzheimer's disease, as measured with a saccade choice task. *Frontiers in Integrative Neuroscience*, 8, article 60. <https://doi.org/10.3389/fnint.2014.00060>
- Bozeat, S., Lambon-Ralph, M. A., Graham, K. S., Patterson, K., Wilkin, H., Rowland, J., & Hodges, J. R. (2003). A duck with four legs: Investigating the structure of conceptual knowledge using picture drawing in semantic dementia. *Cognitive Neuropsychology*, 20(1), 27-47. <https://doi.org/10.1080/02643290244000176>
- Bozeat, S., Patterson, K., & Hodges, J. R. (2004). Relearning object use in semantic dementia. *Neuropsychological Rehabilitation*, 134(3), 351-363. <https://doi.org/10.1080/09602010343000264>

- Bozeat, S., Ralph, M. A., Graham, K. S., Patterson, K., Wilkin, H., Rowland, J., Rogers, T. T., & Hodges, J. R. (2003). A duck with four legs: Investigating the structure of conceptual knowledge using picture drawing in semantic dementia. *Cognitive Neuropsychology*, 20, 27-47. <https://doi.org/10.1080/02643290244000176>
- Breton, A., Casey, D., & Arnaoutoglou, N. A. (2019). Cognitive tests for the detection of mild cognitive impairment (MCI), the prodromal stage of dementia: Meta-analysis of diagnostic accuracy studies. *International Journal of Geriatric Psychiatry*, 34(2), 233-242. <https://doi.org/10.1002/gps.5016>
- Carrion, C., Folkvord, F., Anastasiadou, D., & Aymerich, M. (2018). Cognitive therapy for dementia patients: A systematic review. *Dementia and Geriatric Cognitive Disorders*, 46(1-2). <https://doi.org/10.1159/000490851>
- Charles, R. F., & Hillis, A. E. (2005). Posterior cortical atrophy: Clinical presentation and cognitive deficits compared to Alzheimer's disease. *Behavioural Neurology*, 16(1), 15-23. <https://content.iospress.com/articles/behavioural-neurology/ben00106>
- Ciesielska, N., Sokolowski, R., Mazur, E., Podhorecka, M., Polak-Szabela, A., & Kedziora-Kornatowska, K. (2016). Is the Montreal Cognitive Assessment (MoCA) test better suited than the Mini-Mental State Examination (MMSE) in mild cognitive impairment (MCI) detection among people aged over 60? Meta-analysis. *Psychiatria Polska*, 50(5), 1039-1052. <https://doi.org/10.12740/PP/45368>
- Cohn, N. (2012). Explaining 'I Can't Draw': Parallels between the structure and development of language and drawing. *Human Development*, 55(4), 167-192. <https://doi.org/10.1159/000341842>
- Contador, I., del Ser, T., Llamas, S., Villarejo, A., Benito-León, J., & Bermejo-Pareja, F. (2017). Impact of literacy and years of education on the diagnosis of dementia: A population-based study. *Journal of Clinical and Experimental Neuropsychology*, 39(2), 112-119. <https://doi.org/10.1080/13803395.2016.1204992>
- Dell'Acqua, R., Lotto, L., & Job, R. (2000). Naming times and standardized norms for the Italian PD/DPSS set of 266 pictures: Direct comparisons with American, English, French, and Spanish published databases. *Behavior Research Methods, Instruments, & Computers*, 32(4), 588-615. <https://doi.org/10.3758/BF03200832>
- Deregowski, J. B., & Dziurawiec, S. (1996). The puissance of typical contours and children's drawings. *Australian Journal of Psychology*, 48(2), 98-103. <https://doi.org/10.1080/00049539608259512>
- Dilks, D. D., Julian, J. B., Paunov, A. M., & Kanwisher, N. (2013). The occipital place area is causally and selectively involved in scene perception. *The Journal of Neuroscience*, 33(4), 1331. <https://doi.org/10.1523/JNEUROSCI.4081-12.2013>
- Drake, J. E. (2013). Is superior local processing in the visuospatial domain a function of drawing talent rather than autism spectrum disorder? *Psychology of Aesthetics, Creativity, and the Arts*, 7(2), 203-209. <https://doi.org/10.1037/a0030636>
- Drake, J. E., Redash, A., Coleman, K., Haimson, J., & Winner, E. (2010). 'Autistic' local processing bias also found in children gifted in realistic drawing. *Journal of Autism and Developmental Disorders*, 40(6), 762-773. <https://doi.org/10.1007/s10803-009-0923-0>

- Drake, J. E., & Winner, E. (2011). Realistic drawing talent in typical adults is associated with the same kind of local processing bias found in individuals with ASD. *Journal of Autism and Developmental Disorders*, 41(9), 1192-1201. <https://doi.org/10.1007/s10803-010-1143-3>
- Duff, K., Beglinger, L., Schultz, S., Moser, D. J., McCaffrey, R. J., Haase, R. F., & Huntington's Study Group. (2007). Practice effects in the prediction of long-term cognitive outcome in three patient samples: a novel prognostic index. *Archives of Clinical Neuropsychology*, 22(1), 15-24. <https://doi.org/10.1016/j.acn.2006.08.013>
- Ferber, S., Mraz, R., Baker, N., & Graham, S. J. (2007). Shared and differential neural substrates of copying versus drawing: a functional magnetic resonance imaging study. *NeuroReport*, 18(11), 1089-1093. <https://doi.org/10.1097/wnr.0b013e3281ac2143>
- Fink, W. L. (1982). The conceptual relationship between ontogeny and phylogeny. *Paleobiology*, 8(3), 254-264. <https://doi.org/10.1017/S0094837300006977>
- Goodale, M. A., & Humphrey, G. K. (1998). The objects of action and perception. *Cognition*, 67(1-2), 181-207.
- Graham, D. J., Stockinger, S., & Leder, H. (2013). An island of stability: Art images and natural scenes—but not natural faces—show consistent esthetic response in Alzheimer's-related dementia. *Frontiers in Psychology*, article 4. <https://doi.org/10.3389/fpsyg.2013.00107>
- Grossman, M., Koenig, P., Glosser, G., DeVita, C., Moore, P., Rhee, J., Detre, J., Alsop, D., & Gee, J. (2003). Neural basis for semantic memory difficulty in Alzheimer's disease: an fMRI study. *Brain*, 126(2), 292-311. <https://doi.org/10.1093/brain/awg027>
- Guo, C. C., Gorno-Tempini, M. L., Gesierich, B., Henry, M., Trujillo, A., Shany-Ur, T., Jovicich, J., Robinson, S. D., Kramer, J. H., Rankin, K. P., Miller, B. L., & Seeley, W. W. (2013). Anterior temporal lobe degeneration produces widespread network-driven dysfunction. *Brain*, 136(10), 2979-2991. <https://doi.org/10.1093/brain/awt222>
- Happé, F., & Frith, U. (2010). Introduction: The beautiful otherness of the autistic mind. In F. Happé & U. Frith (Eds.), *Autism and talent* (pp. xi-xx). Oxford University Press.
- Hebb, D. O. (2002). *The organization of behavior: A neuropsychological theory*. L. Erlbaum Ass.
- Hollingworth, A. (2009). Two forms of scene memory guide visual search: Memory for scene context and memory for the binding of target object to scene location. *Visual Cognition*, 17(1-2), 273-291. <https://doi.org/10.1080/13506280802193367>
- Hoogendam, Y. Y., van der Lijn, F., Vernooij, M. W., Hofman, A., Niessen, W. J., van der Lugt, A., Ikram, M. A., & van der Geest, J. N. (2014). Older age relates to worsening of fine motor skills: A population-based study of middle-aged and elderly persons. *Frontiers in Aging Neuroscience*, 6, article 259. <https://doi.org/10.3389/fnagi.2014.00259>
- Hoyek, N., Collet, C., Fargier, P., & Guillot, A. (2012). The use of the Vandenberg and Kuse mental rotation test in children. *Journal of Individual Differences*, 33(1), 62-67. <https://doi.org/10.1027/1614-0001/a000063>

- Hulme, C., Lee, G., & Brown, G. D. (1993). Short-term memory impairments in Alzheimer-type dementia: Evidence for separable impairments of articulatory rehearsal and long-term memory. *Neuropsychologia*, 31(2), 161-172. [https://doi.org/10.1016/0028-3932\(93\)90044-z](https://doi.org/10.1016/0028-3932(93)90044-z)
- Hurley, R. S., Bonakdarpour, B., Wang, X., & Mesulam, M.-M. (2015). Asymmetric connectivity between the anterior temporal lobe and the language network. *Journal of Cognitive Neuroscience*, 27(3), 464-473. https://doi.org/10.1162/jocn_a_00722 %M 25244113
- Irish, M. (2016). Elucidating a core semantic network in the brain—Implications for disorders of semantic cognition. *The Journal of Neuroscience*, 36(23), 6144. <https://doi.org/10.1523/JNEUROSCI.1005-16.2016>
- Irish, M., Piguet, O., Hodges, J. R., & Hornberger, M. (2013). Common and unique gray matter correlates of episodic memory dysfunction in frontotemporal dementia and Alzheimer's disease. *Human Brain Mapping*, 35(4), 1422-1435. <https://doi.org/10.1002/hbm.22263>
- Jolley, R. P. (2010). *Children and pictures: Drawing and understanding*. Wiley-Blackwell.
- Jørgensen, I. F., Aguayo-Orozco, A., Lademann, M., & Brunak, S. (2020). Age-stratified longitudinal study of Alzheimer's and vascular dementia patients. *Alzheimer's & Dementia*, 16(6), 908-917. <https://doi.org/10.1002/alz.12091>
- Kail, R., & Park, Y., S. (1990). Impact of practice on speed of mental rotation. *Journal of Experimental Child Psychology*, 49(2), 227-244. [https://doi.org/10.1016/0022-0965\(90\)90056-E](https://doi.org/10.1016/0022-0965(90)90056-E)
- Karmiloff-Smith, A. (1990). Constraints on representational change: Evidence from children drawing. *Cognition*, 34(1), 53-83. [https://doi.org/10.1016/0010-0277\(90\)90031-e](https://doi.org/10.1016/0010-0277(90)90031-e)
- Kim, H. J., Yang, Y., Oh, J. G., Oh, S., Choi, H., Kim, K. H., & Kim, S. H. (2016). Effectiveness of a community-based multidomain cognitive intervention program in patients with Alzheimer's disease. *Geriatrics & Gerontology International*, 16(2), 191-199. <https://doi.org/10.1111/ggi.12453>
- Kitabayashi, Y., Ueda, H., Narumoto, J., Nakamura, K., Kita, H., & Fukui, K. (2001). Qualitative analyses of clock drawings in Alzheimer's disease and vascular dementia. *Psychiatry and Clinical Neuroscience*, 55(5), 485-491. <https://doi.org/10.1046/j.1440-1819.2001.00894.x>
- Kolanowski, A., Fick, D., Litaker, M., Mulhall, P., Clare, L., Hill, N., & Yevchak-Sillner, A. (2016). Effect of Cognitively stimulating activities on symptom management of delirium superimposed on dementia: a randomized controlled trial. *Journal of the American Geriatrics Society*, 64(12), 2424-2432. <https://doi.org/10.1111/jgs.14511>
- Krampe, R. T. (2002). Aging, expertise and fine motor movement. *Neuroscience & Biobehavioral Reviews*, 26(7), 769-776. [https://doi.org/https://doi.org/10.1016/S0149-7634\(02\)00064-7](https://doi.org/https://doi.org/10.1016/S0149-7634(02)00064-7)
- Kukull, W. A., Higdon, R., Bowen, J. D., McCormick, W. C., Teri, L., Schellenberg, G. D., van Belle, G., Jolley, L., & Larson, E. B. (2002). Dementia and Alzheimer Disease Incidence: A Prospective Cohort Study. *Archives of Neurology*, 59(11), 1737-1746. <https://doi.org/10.1001/archneur.59.11.1737>
- Lange-Küttner, C. (1997). Development of size modification of human figure drawings in spatial axes systems of varying complexity. *Journal of Experimental Child Psychology*, 66, 264-278. <https://doi.org/DOI:10.1006/jecp.1997.2386>

- Lange-Küttner, C. (1998). Pressure, velocity and time in speeded drawing of basic graphic pattern by young children. *Perceptual and Motor Skills*, 86, 1299-1310. <https://doi.org/10.2466/pms.1998.86.3c.1299>
- Lange-Küttner, C. (2004). More evidence on size modification in spatial axes system of varying complexity. *Journal of Experimental Child Psychology*, 88, 171-192. <https://doi.org/10.1016/j.jecp.2004.02.003>
- Lange-Küttner, C. (2009). Habitual size and projective size: The logic of spatial systems in children's drawings. *Developmental Psychology*, 45(4), 913-927. <https://doi.org/10.137/a0016133>
- Lange-Küttner, C. (2011). Sex differences in visual realism in drawings of animate and inanimate objects. *Perceptual and Motor Skills*, 113(2), 439-453. <https://doi.org/10.2466/04.10.24.PMS.113.5.439-453>
- Lange-Küttner, C., & Ebersbach, M. (2013). Girls in detail, boys in shape: Gender differences when drawing cubes in depth. *British Journal of Psychology*, 104(3), 413-437. <https://doi.org/10.1111/bjop.12010>
- Lange-Küttner, C., & Green, H. (2007). What is the age of mental rotation ? *Proceedings of the 6th IEEE International Conference on Development and Learning, IEEE Press*, 259-263. <https://doi.org/10.1109/DEVLRN.2007.4354043>
- Lange-Küttner, C., Küttner, E., & Chromekova, M. (2014). Deterioration and recovery of DAP IQ scores in the repeated assessment of the Naglieri Draw-A-Person (DAP) test in 6- to 12-year-old children. *Psychological Assessment*, 26(1), 297-306. <https://doi.org/10.1037/a0034581>
- Lange-Küttner, C., Kerzmann, A., & Heckhausen, J. (2002). The emergence of visually realistic contour in the drawing of the human figure. *British Journal of Developmental Psychology*, 20(3), 439-463. <https://doi.org/10.1348/026151002320620415>
- Lawson, R. (1999). The effects of view in depth on the identification of line drawings and silhouettes of familiar objects: Normality and pathology. *Visual Cognition*, 6(2), 165-195. <https://doi.org/10.1080/713756808>
- Lenoble, Q., Bubbico, G., Szaflarczyk, S., Pasquier, F., & Boucart, M. (2015). Scene categorization in Alzheimer's Disease: A saccadic choice task. *Dementia and Geriatric Cognitive Disorders*, 5(1), 1-12. <https://doi.org/10.1159/000366054>
- Lenoble, Q., Corveleyn, X., Szaflarczyk, S., Pasquier, F., & Boucart, M. (2018). Attentional capture by incongruent object/background scenes in patients with Alzheimer disease. *Cortex*, 107, 4-12. <https://doi.org/10.1016/j.cortex.2018.06.002>
- Lin, F., Heffner, K. L., Ren, P., Tivarus, M. E., Brasch, J., Chen, D.-G., Mapstone, M., Porsteinsson, A. P., & Tadin, D. (2016). Cognitive and neural effects of vision-based speed-of-processing training in older adults with amnesic mild cognitive impairment: A pilot study. *Journal of the American Geriatrics Society*, 64(6), 1293-1298. <https://doi.org/10.1111/jgs.14132>
- Lin, Q., Luo, J., Wu, Z., Shen, F., & Sun, Z. (2015). Characterization of fine motor development: Dynamic analysis of children's drawing movements. *Human Movement Science*, 40, 163-175. <https://doi.org/10.1016/j.humov.2014.12.010>
- Lindenberger, U., Brehmer, Y., Kliegl, R., & Baltes, P. B. (2008). Benefits of graphic design expertise in old age: Compensatory effects of a graphical lexicon? In C. Lange-Küttner & A. Vinter (Eds.), *Drawing*

and the non-verbal mind: A life-span perspective. (pp. 261-280). Cambridge University Press.
<https://doi.org/10.1017/cbo9780511489730.001>

- Logan, G. D. (1990). Repetition priming and automaticity: Common underlying mechanisms? *Cognitive Psychology*, 22(1), 1-35. [https://doi.org/10.1016/0010-0285\(90\)90002-L](https://doi.org/10.1016/0010-0285(90)90002-L)
- Lövdén, M., Bäckman, L., Lindenberger, U., Schaefer, S., & Schmiedek, F. (2010). A theoretical framework for the study of adult cognitive plasticity. *Psychological Bulletin*, 136(4), 659-676.
<https://doi.org/10.1037/a0020080>
- Luquet, G.-H. (1927/2001). *Children's drawings (Le dessin enfantin) translated by Alan Costall*. International Specialized Book Services.
- Lustig, C., & Buckner, R. L. (2004). Preserved neural correlates of priming in old age and dementia. *Neuron*, 42(5), 865-875. <https://doi.org/10.1016/j.neuron.2004.04.002>
- Lütke, N., & Lange-Küttner, C. (2015). Keeping it in three dimensions: measuring the development of mental rotation in children with the rotated colour cube test (RCCT). *International Journal of Developmental Science*, 9(2), 95-114. <https://doi.org/10.3233/DEV-14154>
- Lütke, N., & Lange-Küttner, C. (2021). The magical number four in children's mental rotation of cube aggregates. *Developmental Psychology*, 57(2), 211-226. <https://doi.org/10.1037/dev0001139>
- Magni, E., Binetti, G., Bianchetti, A., Rozzini, R., & Trabucchi, M. (1996). Mini-Mental State Examination: a normative study in Italian elderly population. *European Journal of Neurology*, 33(3), 198-202.
<https://doi.org/10.1111/j.1468-1331.1996.tb00423.x>
- Marr, D., & Nishihara, N. K. (1978). Representation and recognition of the spatial organisation of three-dimensional shapes. *Proceeding of the Royal Society*, 200, 269-294.
- Mazancova, A. F., Nikolai, T., Stepankova, H., Kopecek, M., & Bezdicek, O. (2016). The reliability of Clock Drawing Test scoring systems modeled on the normative data in healthy aging and nonamnesic Mild Cognitive Impairment. *Assessment*, 24(7), 945-957.
<https://doi.org/10.1177/1073191116632586>
- Mendez, M. F., Mendez, M. A., Martin, R., Smyth, K. M., & Whitehouse, P. J. (1990). Complex visual disturbances in Alzheimer's disease. *Neurology*, 40(3), 439.
https://doi.org/0.1212/WNL.40.3_Part_1.439
- Milbrath, C. (1998). Patterns of artistic development in children: Comparative studies of talent. In T. Houston (Ed.), *Patterns of artistic development in children: Comparative studies of talent*. Cambridge University Press.
- Milbrath, C. (2010). Comparative developmental and social perspectives on the mystery of Upper Paleolithic art. In C. Milbrath & C. Lightfoot (Eds.), *Art and Human Development* (pp. 41-57). Psychology Press.
- Miller, B. L., & Hou, C. E. (2004). Portraits of artists: Emergence of visual creativity in dementia. *Archives of Neurology*, 61(6), 842-844. <https://doi.org/10.1001/archneur.61.6.842>
- Miller, G. A., & Chapman, J. P. (2001). Misunderstanding analysis of covariance. *Journal of Abnormal Psychology*, 110(1), 40-48. <https://doi.org/10.1037/0021-843X.110.1.40>

- Moore, P., Grossman, M., Antani, S., & Koenig, P. (2004). Longitudinal study of semantic memory in Alzheimer's disease. *Brain and Language*, 91(1), 136-137. <https://doi.org/10.1016/j.bandl.2004.06.071>
- Morra, S., & Panesi, S. (2017). From scribbling to drawing: the role of working memory. *Cognitive Development*, 43, 142-158. <https://doi.org/10.1016/j.cogdev.2017.03.001>
- O'Shea, D. M., De Wit, L., Yutsis, M., Castro, M., & Smith, G. E. (2018). Repetition priming in mild cognitive impairment and mild dementia: Impact of educational attainment. *Journal of Clinical and Experimental Neuropsychology*, 40(4), 338-346. <https://doi.org/10.1080/13803395.2017.1347253>
- Patterson, K., & Erzinçlioğlu, S. W. (2008). Drawing as a 'window' on deteriorating conceptual knowledge in neurodegenerative disease. In C. Lange-Küttner & A. Vinter (Eds.), *Drawing and the Non-Verbal Mind* (pp. 281-304). Cambridge University Press. <https://doi.org/10.1017/cbo9780511489730.014>
- Pinto, G., Gamannossi, B. A., & Cameron, C. A. (2011). From scribbles to meanings: Social interaction in different cultures and the emergence of young children's early drawing. *Early Child Development and Care*, 181(4), 425-444. <https://doi.org/10.1080/03004430903442001>
- Plato. (380BC/2013). *The Republic* (C. J. Emlyn-Jones, Trans.). Harvard University Press.
- Ralph, M. A. L. (2001). Semantic memory is impaired in both dementia with Lewy bodies and dementia of Alzheimer's type: a comparative neuropsychological study and literature review. *Journal of Neurology, Neurosurgery & Psychiatry*, 70(2), 149-156. <https://doi.org/10.1136/jnnp.70.2.149>
- Reber, A. S., Allen, R., & Reber, P. J. (1999). Implicit versus explicit learning. In R. J. Sternberg (Ed.), *The nature of cognition* (pp. 475-513). MIT Press.
- Reith, E. (1988). The development of use of contour lines in children's drawings of figurative and non-figurative three-dimensional models. *Archives de Psychologie*, 56(217), 83-103.
- Rémy, F., Saint-Aubert, L., Bacon-Macé, N., Vayssière, N., Barbeau, E., & Fabre-Thorpe, M. (2013). Object recognition in congruent and incongruent natural scenes: A life-span study. *Vision Research*, 91, 36-44. <https://doi.org/10.1016/j.visres.2013.07.006>
- Rensink, R. A. (2000). Scene Perception. In *Encyclopaedia of Psychology* (Vol. 7, pp. 151-155). Oxford University Press.
- Salthouse, T. A. (1991). Age and experience effects on the interpretation of orthographic drawings of three-dimensional objects. *Psychology and Aging*, 6(3), 426-433. <https://doi.org/10.1037/0882-7974.6.3.426>
- Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review*, 103(3), 403-428. <https://doi.org/10.1037/0033-295x.103.3.403>
- Schaie, K. W. (1994). The course of adult intellectual development. *American Psychologist*, 49(4), 304-313. <https://doi.org/10.1037/0003-066X.49.4.304>

- Silveri, M. C., Cappa, A., Mariotti, P., & Puopolo, M. (2002). Naming in patients with Alzheimer's Disease: Influence of age of acquisition and categorical effects. *Journal of Clinical and Experimental Neuropsychology*, 24(6), 755-764. <https://doi.org/10.1076/jcen.24.6.755.8407>
- Smith, C. D., Umberger, G. H., Manning, E. L., Slevin, J. T., Wekstein, D. R., Schmitt, F. A., Markesbery, W. R., Zhang, Z., Gerhardt, G. A., Kryscio, R. J., & Gash, D. M. (1999). Critical decline in fine motor hand movements in human aging. *Neurology*, 53(7), 1458. <https://doi.org/10.1212/WNL.53.7.1458>
- Smith, L. B., Yu, C., & Pereira, A. F. (2011). Not your mother's view: The dynamics of toddler visual experience. *Developmental Science*, 14(1), 9-17. <https://doi.org/10.1111/j.1467-7687.2009.00947.x>
- Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Human Learning and Memory*, 6(2), 174-215. <https://doi.org/10.1037/0278-7393.6.2.174>
- Tabatabaey-Mashadi, N., Sudirman, R., Khalid, P. I., & Lange-Küttner, C. (2015). Automated syntax analyses of drawing two tangent patterns in children with low and average handwriting ability. *Perceptual and Motor Skills*, 120(3), 865-894. <https://doi.org/10.2466/24.10.PMS.120v15x1>
- Talwar, N. A., Churchill, N. W., Hird, M. A., Pshonyak, I., Tam, F., Fischer, C. E., Graham, S. J., & Schweizer, T. A. (2019). The neural correlates of the Clock-Drawing Test in healthy aging. *Frontiers in Human Neuroscience*, 13, article 25. <https://doi.org/10.3389/fnhum.2019.00025>
- Tettamanti, M., & Marcon, G. (2018). Cohort profile: 'Centenari a Trieste' (CaT), a study of the health status of centenarians in a small defined area of Italy. *BMJ open*, 8(2), e019250-e019250. <https://doi.org/10.1136/bmjopen-2017-019250>
- Then, F. S., Luck, T., Angermeyer, M. C., & Riedel-Heller, S. G. (2016). Education as protector against dementia, but what exactly do we mean by education? *Age and Ageing*, 45(4), 523-528. <https://doi.org/10.1093/ageing/afw049>
- Trojano, L., & Gainotti, G. (2016). Drawing disorders in Alzheimer's disease and other forms of dementia. *Journal of Alzheimer's Disease*, 53(1), 31-52. <https://doi.org/10.3233/JAD-160009>
- Tzuriel, D., & Egozi, G. (2010). Gender differences in spatial ability of young children: The effects of training and processing strategies. *Child Development*, 81(5), 1417-1430. <https://doi.org/10.1111/j.1467-8624.2010.01482.x>
- Venturelli, M., Sollima, A., Cè, E., Limonta, E., Bisconti, A. V., Brasioli, A., & Esposito, F. (2016). Effectiveness of exercise- and cognitive-based treatments on salivary cortisol levels and sundowning syndrome symptoms in patients with Alzheimer's Disease. *Journal of Alzheimer's Disease*, 253(4), 1631-1640. <https://doi.org/10.3233/jad-160392>
- Verguts, T., & Notebaert, W. (2008). Hebbian learning of cognitive control: Dealing with specific and nonspecific adaptation. *Psychological Review*, 115(2), 518-525. <https://doi.org/10.1037/0033-295x.115.2.518>
- Voelcker-Rehage, C. (2008). Motor-skill learning in older adults—a review of studies on age-related differences. *European Review of Aging and Physical Activity*, 5(1), 5-16. <https://doi.org/10.1007/s11556-008-0030-9>

- von Károlyi, C., & Winner, E. (2005). Extreme Giftedness. In R. J. Sternberg & J. E. Davidson (Eds.), *Conceptions of giftedness (2nd ed.)*. (pp. 377-394). Cambridge University Press.
<https://doi.org/10.1017/cbo9780511610455.022>
- Willats, J. (2005). *Making sense of children's drawings*. Lawrence Erlbaum.
- Winner, E., & Drake, J. E. (2013). The rage to master: The decisive role of talent in the visual arts. In S. B. Kaufman (Ed.), *The complexity of greatness: Beyond talent or practice*. (pp. 333-365). Oxford University Press.
- Witkin, H. A., Oltman, P. K., Raskin, E., & Karp, S. A. (1971). *Manual for embedded figures test, children's embedded figures test, and group embedded figures test*. Consulting Psychologists Press.
- World Health Organization. (2017). *Global action plan on the public health response to dementia 2017-2025*.
https://www.who.int/mental_health/neurology/dementia/action_plan_2017_2025/en/.
- Wright, R., Thompson, W. L., Ganis, G., Newcombe, N. S., & Kosslyn, S. M. (2008). Training generalized spatial skills. *Psychonomic Bulletin & Review*, 15(4), 763-771. <https://doi.org/10.3758/PBR.15.4.763>
- Yang, Q., Guo, Q.-H., & Bi, Y.-C. (2015). The brain connectivity basis of semantic dementia: A selective review. *CNS Neuroscience & Therapeutics*, 21(10), 784-792. <https://doi.org/10.1111/cns.12449>
- Zeidman, P., & Maguire, E. A. (2016). Anterior hippocampus: the anatomy of perception, imagination and episodic memory. *Nature Reviews Neuroscience*, 17, 173. <https://doi.org/10.1038/nrn.2015.24>

Figure Legends

- Fig. 1. Screen Shots of the Computerized Tasks, **1A**. Object Naming, **1B** Scene Context, **1C** Object Drawing
- Fig. 2. Performance Improvement over Five Days of Training. **2A** Semantic Memory **2B** Scene Perception **2C** Object Drawing. Error bars denote the Standard Error. Accuracy and reaction time scores are controlled for age, years in education and years in retirement.
- Fig. 3. Drawing Series over Five Days of Training. AD group (top row), Control group (bottom row) **3A** Penguin drawings (example for shape modification and added details), **3B** Horse drawings (example for shape closure and modification and addition of detail)
- Fig. 4. Correlations of the three visual cognition tasks on Days 1-5 (accuracy on the left; response times on the right)

FIGURE 1

(1A) Object naming task with on-screen response buttons **(1B)** Scene Context Choice task with on-screen response by touch **(1C)** Drawing task with on-screen instruction

(2A) Semantic Memory (Object Naming)

(2B) Scene Perception (Object-in-Context)

FIGURE 2

(2C) Object Drawing

FIGURE 3

FIGURE 4

(4A) Penguin Drawings

to be continued on the following page

Day 1

Day 2

Day 3

Day 4

Day 5

(4B) Horse Drawing

Table 1*Participant Variables (t-tests for independent groups)*

	Control (n=10)	Dementia (n=10)	<i>df</i>	<i>t</i>	<i>p</i>	<i>Cohen's d</i>
Gender	3 Males	2 Males				
Age in years	76 (66-83)	82 (69-90)	15.33	-2.16	.047*	5.79
MMSE score (max. 30)	26.15 (1.17)	20.88 (2.41)	13.06	6.22	.001***	1.89
Years of education	8-12 years	5-7 years	18	3.84	.001***	.70
Years of retirement	14 (7)	27 (11)	18	-3.16	.005**	9.19

Note. Numbers in brackets represent the Range (Age) or the Standard Deviation.

Table 2*Visual Cognition Tasks: Pearson Correlations between Days (two-tailed) (N = 20)*

Task	Day 1-2	Day 2-3	Day 3-4	Day 4-5
<u>Total Sample</u>				
Semantic memory accuracy	.67**	.63**	.35	.41
Object-in-scene accuracy	.90**	.88**	.35	.29
Drawing accuracy	.95**	.94**	.93**	.90**
Semantic memory latencies	.55*	.51*	.26	.55*
Object-in-scene latencies	.82**	.71**	.72**	.80**
Drawing time	.83**	.72**	.66**	.57**
<u>AD Group</u>				
Semantic memory accuracy	.41	.41	.14	.27
Object-in-scene accuracy	.80**	.58	-.22	.25
Drawing accuracy	.91**	.95**	.94**	.96**
Semantic memory latencies	.84**	.41	.35	.60
Object-in-scene latencies	.67*	.26	.38	.51
Drawing time	.93**	.91**	.76**	.59
<u>Control Group</u>				
Semantic memory accuracy	.51	.51	.22	n/a
Object-in-scene accuracy	.80**	.74*	.69*	.32
Drawing accuracy	.94**	.85**	.82**	.57
Semantic memory latencies	.37	.53	.08	.49
Object-in-scene latencies	.50	.89**	.60	.83**
Drawing time	.82**	.41	.50	.48

Note. Correlations of drawing accuracy and drawing time are set in bold.

** = Correlation is significant at the .01 level; * = Correlation is significant at the .05 level

Table 3*Accuracy in % for Semantic memory, Scene perception and Drawing (2-tailed t-tests)*

Dementia			Control			<i>t</i>	<i>df</i>	<i>p</i>
<i>Day</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>CI</i>			
Semantic Memory								
1	88.5	6.7	98.5	2.4	5.3, 14.72	4.45*	11.3	.001
2	95.0	4.1	99.5	1.6	1.60, 7.41	3.25	11.6	.007
3	95.5	4.4	99.5	1.6	.91, 7.09	2.71	11.3	.020
4	97.0	3.5	99.0	2.1	-.71, 4.71	1.55	14.8	.142
5	99.0	2.1	100.0	0.0	-.40, 2.40	1.50	9	.168
Scene Perception								
1	72.0	8.9	95.0	5.3	16.13, 29.86	7.04*	18	.000
2	80.5	7.6	93.5	5.3	6.83, 19.21	4.43*	18	.000
3	81.5	5.3	94.5	5.0	8.17, 17.83	5.66*	18	.000
4	90.0	5.8	94.0	6.2	-1.60, 9.60	1.50	18	.151
5	96.0	3.9	97.5	4.9	-2.66, 5.66	.76	18	.458
Drawing								
1	41.3	21.5	75.6	15.4	16.70, 51.81	4.10*	18	.001
2	50.4	21.8	86.9	9.6	20.68, 52.28	4.85*	12.4	.000
3	61.8	21.2	92.1	6.5	15.58, 45.01	4.33*	10.7	.001
4	68.3	19.0	93.4	5.7	11.86, 38.27	3.99*	10.6	.002
5	77.7	17.0	95.3	4.7	5.87, 29.33	3.15	10.4	.010

Note. Bonferroni-corrected significance threshold of $p = .003$

Table 4*Reaction times in semantic memory, scene perception and completion duration drawing times*

Dementia			Control		CI	t	df	p
Day	M	SD	M	SD				
Semantic Memory								
1	7012.9	1979.3	6034.9	2815.8	-98, 1.09	-0.89	11.8	.381
2	6982.8	1612.0	4531.4	2105.5	-2.45, .84	-2.92	18	.009
3	6052.0	1589.3	3847.5	1892.0	-22.0, .78	-2.82	18	.011
4	5489.6	1368.8	3863.0	1457.6	-1.63, .63	-2.57	18	.019
5	4166.1	945.0	3171.2	920.7	-.99, .41	-2.38	18	.028
Scene Perception								
1	11253.0	3804.1	5307.2	2353.2	-5.94, 1.41	-4.20	18	.001
2	9881.3	3703.5	4110.5	1302.7	-5.77, 1.24	-4.64	11.2	.001
3	8756.9	3054.0	3867.4	1760.2	-4.89, 1.11	-4.38	18	.000
4	7028.9	1360.5	3683.7	1985.2	-3.35, .76	-4.39	18	.000
5	5614.3	1667.4	2921.5	1069.6	-2.69, .63	-4.29	18	.000
Drawing								
1	84487.1	45543.6	65589.5	43188.6	-18.89, 19.85	-0.95	18	.345
2	90647.4	51673.3	54920.7	20567.3	-35.73, 17.59	-2.03	18	.065
3	98483.3	50581.0	68590.6	32412.3	-29.89, 19.00	-1.57	18	.133
4	101302.5	55262.3	61955.6	27540.7	-39.34, 19.53	-2.01	18	.065
5	102317.3	48995.9	67542.3	29650.3	-34.77, 18.11	-1.92	18	.071

Note. Bonferroni-corrected significance threshold of $p = .003$.

Table 5*Prediction of Drawing Accuracy: Multiple Regression Per Day (N = 20)*

	<i>B</i>	<i>SE</i>	<i>Beta</i>	<i>t</i>	<i>p</i>	95% CI for B
<u>Day 1</u>						
MMSE	1.77	2.26	.23	.78	.447	[-3.1, 6.7]
Semantic memory accuracy	1.02	.81	.29	1.26	.230	[-0.7, 2.8]
Object-in-scene accuracy	.39	.31	.21	1.25	.235	[-0.3, 1.1]
Semantic memory latencies	.00	.00	-.16	-.85	.411	[0.0, 0.0]
Object-in-scene latencies	.00	.00	-.27	-.94	.366	[0.0, 0.0]
Drawing time	.00	.00	.40	2.57	.023*	[0.0, 0.0]
<u>Day 2</u>						
MMSE	1.26	1.41	.16	.89	.389	[-1.8, 4.3]
Semantic memory accuracy	1.26	1.04	.19	1.21	.249	[-1.0, 3.5]
Object-in-scene accuracy	-.36	.42	-.13	-.86	.405	[-1.3, 0.5]
Semantic memory latencies	.00	.00	-.03	-.26	.799	[0.0, 0.0]
Object-in-scene latencies	.00	.00	-1.27	-5.93	.000**	[0.0, 0.0]
Drawing time	.00	.00	.89	5.28	.000**	[0.0, 0.0]
<u>Day 3</u>						
MMSE	2.72	1.48	.41	1.83	.090	[-0.5, 5.9]
Semantic memory accuracy	1.14	.91	.20	1.24	.235	[-0.8, 3.1]
Object-in-scene accuracy	-.49	.55	-.19	-.89	.387	[-1.7, 0.7]
Semantic memory latencies	.00	.00	.01	.04	.968	[0.0, 0.0]
Object-in-scene latencies	-.00	.00	-.87	-4.12	.001**	[0.0, 0.0]
Drawing time	.00	.00	.54	3.09	.009**	[0.0, 0.0]
<u>Day 4</u>						
MMSE	2.86	1.38	.50	2.07	.059(*)	[-0.1, 5.8]
Semantic memory accuracy	.67	1.46	.11	.46	.654	[-2.5, 3.8]
Object-in-scene accuracy	.94	.61	.31	1.53	.150	[-0.4, 2.3]
Semantic memory latencies	.00	.00	-.05	-.24	.815	[0.0, 0.0]
Object-in-scene latencies	.00	.00	-.25	-.72	.482	[0.0, 0.0]
Drawing time	.00	.00	.28	1.00	.335	[0.0, 0.0]
<u>Day 5</u>						
MMSE	1.45	1.07	.31	1.35	.199	[-0.9, 3.8]
Semantic memory accuracy	1.24	1.70	.13	.73	.480	[-2.4, 4.9]
Object-in-scene accuracy	.15	.57	.04	.27	.792	[-1.1, 1.4]
Semantic memory latencies	.00	.00	.06	.28	.786	[0.0, 0.0]
Object-in-scene latencies	-.01	.00	-.78	-2.49	.027*	[0.0, 0.0]
Drawing time	.00	.00	.45	2.26	.041*	[0.0, 0.0]

Table 6*Prediction of Drawing Accuracy: Multiple Regression Per Day (N = 20) with Pre-Session Drawing Score*

	<i>B</i>	<i>SE</i>	<i>Beta</i>	<i>t</i>	<i>p</i>	95% CI for B
<u>Day 2</u>						
MMSE	.02	1.10	.00	.02	.987	[-2.4, 2.4]
Semantic memory accuracy	.82	.78	.12	1.05	.313	[-0.9, 2.5]
Object-in-scene accuracy	-.19	.32	-.07	-.61	.550	[-0.9, 0.5]
Semantic memory latencies	.00	.00	.01	.07	.943	[0.0, 0.0]
Object-in-scene latencies	.00	.00	-.68	-2.93	.013*	[0.0, 0.0]
Drawing time	.00	.00	.44	2.42	.032*	[0.0, 0.0]
Drawing Day 1	.54	.16	.55	3.44	.005**	[0.2, 0.9]
<u>Day 3</u>						
MMSE	.20	.66	.03	.31	.762	[-1.2, 1.6]
Semantic memory accuracy	.28	.37	.05	.76	.464	[-0.5, 1.1]
Object-in-scene accuracy	-.34	.22	-.13	-1.58	.141	[-0.8, 0.1]
Semantic memory latencies	.00	.00	.00	-.06	.957	[0.0, 0.0]
Object-in-scene latencies	.00	.00	-.15	-1.22	.247	[0.0, 0.0]
Drawing time	.00	.00	.06	.73	.481	[0.0, 0.0]
Drawing Day 2	.82	.10	.93	8.44	.000**	[0.6, 1.0]
<u>Day 4</u>						
MMSE	-.42	.40	-.07	-1.04	.320	[-1.3, 0.5]
Semantic memory accuracy	.50	.35	.08	1.42	.180	[-0.3, 1.3]
Object-in-scene accuracy	.06	.16	.02	.35	.733	[-0.3, 0.4]
Semantic memory latencies	.00	.00	.00	-.06	.956	[0.0, 0.0]
Object-in-scene latencies	.00	.00	-.07	-.79	.443	[0.0, 0.0]
Drawing time	.00	.00	.08	1.14	.277	[0.0, 0.0]
Drawing Day 3	.85	.06	1.0	14.55	.000**	[0.7, 1.0]
<u>Day 5</u>						
MMSE	-.17	.54	-.04	-.31	.763	[-1.3, 1.0]
Semantic memory accuracy	-1.12	.85	-.11	-1.31	.213	[-3.0, 0.7]
Object-in-scene accuracy	.26	.26	.08	1.01	.334	[-0.4, 0.8]
Semantic memory latencies	.00	.00	.18	1.70	.116	[0.0, 0.0]
Object-in-scene latencies	.00	.00	-.02	-.09	.926	[0.0, 0.0]
Drawing time	.00	.00	-.16	-1.28	.225	[0.0, 0.0]
Drawing Day 4	.83	.12	1.03	7.05	.000**	[0.6, 1.1]