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Far transfer in cognitive training of older adults

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Abstract

Purpose—This article reviews the literature on far transfer effects in training of older adults.

Methods—Adapting a taxonomy of transfer developed by Barnett and Ceci (2002), to rehabilitation or enhancement of existing cognitive skills; results of studies assessing transfer effects from training of memory, reasoning, UFOV, dual task performance, and complex training are classified.

Results—Comparisons of the transfer outcomes of both strategy training and extended practice approaches suggest that far transfer has been observed.

Conclusions—Outcomes for strategy studies training memory have had less success than extended practice studies in obtaining far transfer. Reasons for this are discussed, as are suggestions for improved assessment of transfer outcomes.

1. Introduction

Several recent reviews point out that, while in general, cognitive training benefits older adults' performance, there is little evidence of transfer to untrained cognitive abilities (e.g., Park et al., 2007), including memory (Rebok et al., 2007), though others suggest that it depends on the approach used (e.g., McDaniel et al., 2008). For the past 100 years, arguments have been made about whether transfer exists or not (Barnett and Ceci, 2002). Barnett and Ceci suggest that the controversy exists because the elements of near and far transfer are neither objectively defined nor directly comparable across studies. They proposed a taxonomy to classify transfer effects as near or far, and this framework provides evidence of transfer. In this article, I will discuss transfer with respect to Barnett and Ceci's taxonomy as applied to studies of aging. I will briefly describe the two broad approaches to training in the aging literature, identify studies in aging suggesting successful far transfer based on the framework, discuss principles of training that produces transfer to memory, and conclude with some thoughts on how to improve measurement of far transfer.

Excellent reviews of the literature on performance improvements on a wide range of cognitive tasks are available in chapters by Kramer and Madden and by McDaniel, Einstein, and Jacoby in the third edition of the *Handbook of Cognition and Aging*, (Craik and Salthouse, 2008), and in a special issue of the *Journal of Gerontology: Psychological*

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Sciences (June, 2007), so the reader is referred to those sources for detailed assessments of training effects.

2. The promise of far transfer

The goal of training older adults is to improve performance in the cognitive skills on which age deficits have been observed. That is, the purpose of training is not to enhance or promote the development of new skills, as in the educational psychology literature, but to rehabilitate skills that are assumed to have declined with aging (e.g., Winocur et al., 2007). The premise on which the rehabilitation rests is that the abilities on which older people show declines are ultimately important to maintaining or improving their everyday cognitive function. Many studies also suggest that cognitive ability is positively associated with functional ability.

Individuals with cognitive impairment have greater physical and functional impairment than those with good cognitive status (Agureo-Tores et al., 2002; see also Monastero et al., 2006), and are more likely to have multiple coexisting diseases and conditions (Blaum et al., 2002). Blaum et al. found that low cognitive performance was independently associated with functioning problems, after controlling for education and demographic characteristics, suggesting that cognition is an important predictor of functional status. Decline in cognitive function often accompanies physical declines (Black and Rush, 2002). One explanation for the relationship between cognitive and physical decline is that poor performance on physical function tasks may be related to cognitive difficulties in following directions (Tabbarah et al., 2003). However, this becomes a “chicken and egg” problem in that cognitive difficulties may affect ability to perform activities in everyday life, but neurological function can underlie both mental status and ability to perform tasks (e.g., Li et al., 2001). If this is the case, cognitive interventions may be useful not in only reversing cognitive performance declines but those that might relate to physical functioning (see also Jobe et al., 2001).

Another premise underlying the rationale for rehabilitation of abilities in training older adults is that retraining abilities will ensure the preservation of functional ability. Ball et al., (2007) as well as Willis et al., (2006) have argued that the benefits of training may be less relevant to the enhancement of functional ability, but more relevant to its maintenance, whereby untrained individuals show declines, but those who were trained do not. The ultimate goal of training in aging, whether for reversing declines, or promoting stability, is to support older adults so that they can remain independent longer, an issue with major policy and fiscal implications for aging societies.

2.1. Strategy training versus extended practice

Two major approaches have been used successfully to train older adults in cognitive abilities. Strategy training is a “top down” approach and has been used for training memory, reasoning, and complex planning skills. Extended practice is a “bottom up” approach and has been used for training memory, dual task performance, and attention and discrimination skills. Effects of strategy training are generally measured using paper and pencil psychometric tasks whereas effects of extended practice are generally measured using computerized tasks.

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Strategy training such as use of specific mnemonics (e.g., a mnemonic to remember 4-digit codes; Derwinger et al., 2003) produces improvement in memory performance as does instruction with more general approaches (e.g., Ball et al., 2002). Other work suggests that providing support and instruction for self monitoring of learning and retrieval enhances memory (e.g., Dunlosky et al., 2007). Reasoning abilities also show improvement with instruction in strategies, (e.g., Ball et al., 2002). A multimodular strategy training program that included memory training, psychosocial support, and goal management training (Winocur et al., 2007) for individuals with subjective complaints about memory and cognitive abilities has also been associated with better performance on recall (Craik et al., 2007), global psychosocial functioning (Winocur et al., 2007), and on an everyday complex coordination task such as organizing a carpool, (Levine et al., 2007). Thus strategy training, broadly defined, improves performance on a range of different cognitive tasks compared with untrained controls.

Extended practice has been somewhat less prominent in the aging training literature until recently, but it improves performance. Jennings and Jacoby, (2003) trained discrimination in continuous recognition skills in older adults whereby participants indicated whether items presented one at a time were either from a list studied previously, were new, or had been shown previously as test items. The lag between test list item presentations was varied. By gradually increasing the lag, that is, the number of items intervening between the first presentation of a test item (when it is new) and its subsequent presentation, older adults could accurately identify repeated test items with a lag of 28 items between presentations, in comparison to only being able to identify repeated test items at a lag of 2 without training.

Performance change on response time (RT) tasks with extended practice has also been observed in older adults. Kramer et al., (1999) used a task-switch paradigm for assessment and training of young and older adults. Participants saw rows of identical digits and had to indicate either whether the number of digits or the value of the digits was greater than five. Increases in RT when the task was switched from the number or the valuation to the alternate task were evaluated as *switch costs.* Although older adults had relatively larger switch costs than younger ones early in practice, late in practice the relative costs did not differ from those of young adults.

Dual-task performance has also been evaluated with respect to practice and manipulations. Dual-task studies examine the costs of performing two tasks simultaneously by subtracting the difference in response latency during performance on both tasks from response latency during performance on the tasks performed individually. Kramer et al., (1995) had participants perform simultaneously an alphabet-arithmetic task (K–3 = ?) and a visual monitoring task in a training study. Reduction of dual task latency costs was similar in both young and old adults. Dual task training of either low/high tone discrimination or letter discrimination (*B* or *C*) showed reductions in dual task latency costs with training, relatively greater increases in accuracy (Bherer et al., 2005) and reduction in performance variability (Bherer et al., 2006).

Speed of processing in the UFOV paradigm, whereby participants complete extended practice to increase accuracy in identification of fixated objects at increasingly more rapid

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presentations, in identification of the objects while localizing another target in the periphery relative to fixation, and completing the second task with the peripheral target embedded in distracters, also shows performance improvement (see e.g., Ball et al., 2007, for a summary of the training and findings across multiple studies).

2.2. A taxonomy of transfer

Barnett and Ceci, (2002) devised a taxonomy of transfer framework to compare directly the seemingly disparate sets of findings in the developmental and young adult literature that argue for and against the existence of transfer. They suggested that the problem of transfer has appeared to be insoluble because of “a lack of structure in the transfer debate and a failure to specify the various dimensions that may be relevant to determining whether and when transfer occurs” (p. 614).

They proposed a taxonomy to organize findings and to evaluate the extent of transfer. Their framework identifies dimensions of transfer with respect to content, that is, *what* is transferred, and to context, *when* and *where* transfer occurs. On the content side, Barnett and Ceci, (2002) identified variables that affect the likelihood of transfer: the nature of the skill to be transferred, of the performance change, and the memory demands of the transfer task. Content is embedded in the context of transfer. With respect to context, they suggested that the “near” and “far” distance between the training and transfer contexts occurred along multiple dimensions (knowledge domain, physical context, temporal context, functional context, social context, and modality). I will describe their taxonomy, show its general applicability to aging, then classify selected studies in the relevant domains of the taxonomy.

Content dimensions of transfer—One content dimension is of the continuum from skill specificity to generality, that is, whether the transfer is of a set of specific deterministic and well defined procedures such as an algorithm learned for a cognitive skill, or the transfer is of general strategies, principles, or heuristics, such as “check your work”. Studies using specific procedures can be considered to train “superficial” approaches whereas those using general principles are thought of as training “deep” skills.

The second content dimension of transfer is the type of outcome response against which improvement is expected, such as speed or accuracy. These outcomes can be the same as or different from what was trained. The third dimension is whether memory has to be actively used in order to complete the transfer task because participants have to remember and choose between procedures to apply. Barnett and Ceci suggest that transfer is more likely to occur when deep, general principles have been trained, when the performance measures used for the outcome are identical to those on which the training took place, and when the transfer task requires minimal memory retrieval requirements from the trained task, though there may be interactions and exceptions.

In the skill specificity domain, some studies in the aging literature have trained specific skills, such creating and applying a mnemonic to remember a 4-digit code (e.g., Derwinger et al., 2003). However, strategy training studies evaluating transfer with older adults have more typically trained both specific and more general memory skills – for example, training with task-specific mnemonics as well as providing education on the basic principles of

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memory, as in the ACTIVE (Advanced Cognitive Training for Independent and Vital Elderly) trial (Ball et al., 2002) or the multimodal training study (Winocur et al., 2007). In extended practice studies, participants may be trained on skills with instruction to use specific strategies, but performance gains may not differ from those of participants who practice with no explicit instruction (e.g., Paxton et al., 2006). Recent research with young adults trained to play video games without specific strategy instruction also shows transfer to broader attentional abilities not directly trained (e.g., Green and Bavelier, 2006). This suggests that skills developed during training are not instruction-dependent and show generalized transfer. However, the specificity of transfer skills evaluated in aging research is broader than specific skills described by Barnett and Ceci, (2002).

Both strategy and extended practice studies have assessed performance change on measures of transfer such as response time or accuracy that are identical to those trained. Other transfer measures have been very different, such as ratings on a health-related quality of life scale after training for increased accuracy in reasoning (e.g., Wolinsky et al., 2006).

The memory requirement dimension as described by Barnett and Ceci, (2002) has been not been widely varied in transfer in aging studies, though effects of “support” for the transfer task have been evaluated (e.g., Derwinger et al., 2003). Transfer effects over time have been observed both with and without memory support, though transfer outcomes may be stronger with support (e.g., Derwinger et al., 2005). Because only the studies by Derwinger and associates (2003, 2005) have evaluated memory support for specific strategies in transfer, I will not discuss this further, although memory requirements of transfer tasks may be evaluated in future work. I will describe the content dimensions of skill specificity and performance change with respect to specific aging studies when evaluating where studies lie in the context dimensions of the taxonomy.

Context dimensions of transfer—Barnett and Ceci identify multiple context dimensions of transfer to measure the *distance* between training and transfer skills. The *knowledge domain* is the knowledge base to which the skill is to be applied, that is, from physics to English. *Physical context*, whether the training and the testing occur in the same environment, can range, for example, from different rooms in a research laboratory to the home environment. *Temporal context* is the amount of time between training and transfer, with far transfer increasing over time. *The functional context* is the function for which the skill is positioned and the mind-set it induces, (see Barnett and Ceci, 2002); far transfer involves extending the functional context to one that is very different from that of the skill trained, for example, from handicapping horses at a racetrack to handicapping stocks in the stock market (e.g., Ceci and Liker, 1986). The *social context* is whether the skill is learned or practiced individually or collaboratively, and transfer involves the alternative social milieu. *Modality* can refer to the sensory modality in which the transfer is tested (i.e., visual or auditory) or what type of format is used in transfer (i.e., recall vs. multiple choice test). The complexity of the taxonomy suggests that transfer is highly contextualized, and multiply determined by both content and context. Because content and context are embedded, far transfer context effects may vary because of the content dimensions of transfer.

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Barnett and Ceci, (2002) identify the content dimensions for specific studies in their taxonomy and apply the relevant context dimensions to a hierarchy in which multiple dimensions of transfer can be organized as a continuum of near to far. However, there is no specific indication of how near or far the transfer might be on the dimensions. Far transfer is assumed to be present if transfer tasks have less in common with the original training on these dimensions. Barnett and Ceci's taxonomy is also silent as to a hierarchy of transfer. Instead, near to far is determined by arbitrarily nesting the contexts. Transfer distance is cumulated: if the "far" transfer for multiple context areas is demonstrated, then the study suggests that it is "further" along the far transfer continuum than a study with features that fall in more of the "near" domains. Thus studies that appear furthest to the right in the classification system can be thought of as demonstrating more far transfer than those on the left, but they are not precisely defined with respect to the amount of transfer. For example, the far temporal dimension of transfer could be defined as 2 weeks or 20 years subsequent to training; the framework simply suggests that any timeframe for transfer outside of immediate evaluation is "far".

Context dimensions of transfer and aging—Two of the six context dimensions have been not been directly studied thus far with respect to transfer in the aging literature. Transfer to different knowledge domains has not been studied substantively in aging. Social context has been a part of training studies, whether in the context of group training before individual computer training commences (UFOV; Ball et al., 2002) or in collaborative group discussions (multimodal training; Winocur et al., 2007). Barnett and Ceci, (2002) suggest that that skills learned in a group might not be applied if the participant is tested individually at transfer. However, studies in aging may involve either individual or group pre and post-testing, but collaboration effects have not been an element of the assessment of transfer. The knowledge domain and social context dimensions will not be further addressed in this paper, although transfer effects for these domains could be evaluated in training studies of older adults in the future.

Studies of transfer in older adults have addressed the remaining four context dimensions to varying extents. Physical context transfer has been directly tested, but only rarely, as few studies evaluate transfer effects when training and testing environments differ. The most far transfer in aging with respect to physical context is that of a road test in a specially designed automobile after UFOV training; see below, (Roenker et al., 2003) but here the nature of the performance change, physical, and functional context are conflated. Temporal context has been addressed in recent aging studies with the duration between training and transfer ranging from seven weeks (e.g. van Hooren et al., 2007), to five years (e.g., Willis et al., 2006).

Functional transfer context has been evaluated in aging in a number of ways. Some transfer skills have "nearer" functional contexts, such as supervisory function skills that transfer to different types of elementary tasks (e.g., Kramer et al., 1995), whereas others transfer to "further" functions. For example, visual skills trained with UFOV transfer to driving (Roenker et al., 2003), or to how quickly change can be counted in the Timed Instrumental Activities of Daily Living (Timed IADL) test (Edwards et al., 2005). In aging, far functional transfer can also occur where the skill transfers to everyday functioning, measured as a

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reduction in risk of problems with instrumental activities of daily living (IADLs), (Willis et al., 2006).

Modality transfer in aging studies has been evaluated with respect to both sensory modality of presentation and task format for training and transfer. For example, some of the dual task transfer studies have used only visual training of skills and visual measures to evaluate transfer, therefore not varying modality, (e.g., Kramer et al., 1995), whereas others have trained visual skills, for example, and tested transfer to tasks involving multiple sensory modalities (e.g. Willis et al., 2006). Task format has varied for example, from recognition to recall (Smith et al., 2009).

3. Aging research in the taxonomy of transfer

The studies presented in the next section all demonstrate transfer on some, but not all, tests of transfer. Thus, this is not a comprehensive review of the training literature in aging. Studies were selected only if they reported any significant transfer effects, fit the taxonomy, and were in press or published by September 15, 2008. Several studies involve outcomes that are likely to involve effects not due directly to application of transferred skill, but to the consequences of being able to use the skill, for example, for subjective cognitive functioning abilities. These are described in the Discussion.

The taxonomy of the context dimensions ranging from more near to more far was set up into the hierarchy seen in Table 1. The table shows the three domains of context transfer in which most of the work on transfer has been done in aging. The hierarchy shown in Table 1 is somewhat subjective, with temporal context at the highest level, followed by functional context and by modality. The assumption here is that the length of time for which transfer is observed is the most critical dimension of transfer; the ACTIVE study was predicated on the idea that training effects should endure over years, especially with booster training (Jobe et al., 2001). Even studies showing effects only on the trained skill may be classified as showing far temporal transfer if the effect persists over time. The functional dimension is critically important to far transfer effects in aging: the assumption is that training of cognitive abilities should ultimately transfer to everyday functioning because of the relationship between cognition and functional abilities (Jobe et al., 2001). Transfer in this case reflect skills inherent in everyday functioning. Modality refers in this hierarchy to whether the transfer extends from the sensory or the task format modality to another modality.

Although there are acceptable alternative views about which domain of context transfer is more dominant than the others in the levels of the hierarchy, the point of the exercise here is to show that far transfer has been observed in the aging training literature across multiple context dimensions; how "far" the transfer might be is beyond the scope of the present review. A few studies manipulate the three domains evaluated, but many manipulate only one or two of them. Because some studies have multiple outcome measures that fit different classifications within the domains, I will classify sets of findings from the same study separately in the relevant transfer domains.

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The studies classified in Table 1 are organized by the complexity of skills trained, that is, with training of individual abilities such as memory or reasoning, presented first, dual task training, presented next, and then of complex training involving multiple abilities. Within each level of complexity, strategy training studies are presented before extended practice training studies. Finally, studies are presented in terms of the relative distance of transfer. The studies that can be classified on the furthest right are those showing the furthest transfer. However, even the studies appearing in the leftmost categories show some transfer. Studies only showing effects on the identical skills trained and transferred when tested shortly after training are not presented; there is no column in Table 1 for near transfer in all three context domains. Studies showing no effects of transfer where transfer was tested are also not included, as the purpose of the classification exercise is simply to demonstrate that far transfer exists in the aging training literature.

3.1. Temporal near studies

We begin the classification with studies showing temporal near effects.

Transfer of individual trained abilities: memory and UFOV—Many of the studies in the training literature have focused on training and transfer of individual abilities, such as memory. Specific mnemonic strategy studies have not been successful in producing near transfer to other tasks (see Rebok et al., 2007). Only the extended practice studies directly aimed at improving memory have produced far transfer. Jennings and colleagues, (2005) trained discrimination in retrieval in continuous lagged recognition in older adults as described earlier. They tested transfer with recognition tasks thought to require retrieval of other types of contextual information as well as supervisory processes: n-back identity, self-ordered pointing, and source recognition, and found improvement in the trained group compared to untrained controls on these tasks. The content dimensions in this study involved a relatively generalizable skill: learning discrimination for contextual information in memory, and the performance change involved increases in accuracy, which was identical to that trained. Transfer testing was immediately after training, so the transfer findings are temporal near, involves different functional applications of context recognition, thus, are functional far, and the visual modality, thus modality near. Modality transfer with respect to task format (recognition) was also near.

Smith et al. (2009) trained discrimination and rapid processing of confusable frequency sweeps, phonemes, phrases, and sentences in computerized recognition tasks in the Improvement in Memory with Plasticity-based Adaptive Cognitive Training (IMPACT) study. Testing occurred shortly after training. With respect to the content dimensions of transfer, the skills trained increased in auditory and linguistic complexity, involving increasing generality. In the transfer assessment, the performance change did not differ from training to transfer; it was of accuracy. The outcome tasks that improved significantly all involved transfer of discrimination and memory from the computerized training to neuropsychological assessments, thus were functionally different. Memory for auditory but not visual test materials improved. Thus, the context transfer was temporal near, functional far, and sensory modality near. In this study, the training was of recognition, and the transfer

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tasks all were of recall, indicating that task format modality involved far transfer. This finding is classified as temporal near, functional far, and modality far.

In the UFOV training (Ball et al., 2007), a trainer provided task specific strategies and adapted difficulty levels to the ability of the participant. Participants worked toward specific goals of attaining accuracy for increasingly more difficult tasks at shorter display durations. It is thus a combination of strategy-provided and individual practice approaches, though some UFOV studies include many more hours of strategy training than others. The content domains of the UFOV training transfer speeded visual processing to general speed skills and the performance changes involve accuracy, which are the same as those trained. Roenker et al., (2003) trained drivers with poor UFOV performance on either the UFOV task or on traditional driving training in a simulator. One of the outcome variables was performance on the Road Sign test, a complex response time task developed for the study. Testing for both groups was conducted in the simulator shortly after the completion of training. It involved either making specific responses relevant to the sign (turning right, left, or braking) or withholding responses to road signs with a red slash through them. Those in the UFOV training group had faster responses after training compared with the simulator group. This effect is functional far, as it involves skill transfer to the different functional context of the simulator. This transfer effect is temporal near, and functional far. The sensory modality was visual for training and transfer, but task format modality varied. Here, the trained task involved responses on a computer, whereas the transfer task used manual turning and braking, thus the task modality is far.

Another study compared transfer of UFOV training with that of small-group Internet training with poor UFOV performers to the Timed IADL Test (Timed IADL; Edwards et al., 2005) This test measured performance on five timed visual tasks representing daily activities. These included finding two items in a array of food items on a shelf, finding and reading the instructions on a medicine container, and the speed and accuracy of counting change from a group of coins. Those in the UFOV training group were significantly faster after training on the Timed IADL task than those in the Internet group when tested shortly after training. The transfer effect is temporal near, functional far, and task format modality was far as the skill was transferred to tasks involving hands-on manipulations.

Transfer of dual task training—Bherer et al., (2005) trained older adults in dual task performance of a discrimination of a low (440 Hz) or high tone (990 Hz) performed in combination with a simple visual discrimination task identifying whether a letter was *B* or *C*. They tested immediate transfer to an auditory discrimination task using the same pitch (550 Hz) but a smooth (sine wave) or rough (triangle) sounds and a visual identification task discriminating between two digits, or a cross modal task in which the auditory tasks were combined with visual pattern and number discrimination. For both auditory and cross-modality transfer tasks, trained participants showed a dual task cost reduction not seen for the control group. The content dimensions for this study involved dual task improvement, which involves some skill generalization, the performance change for transfer assessed with speed and accuracy, as well as by costs, and did not differ from the trained skills. This task was temporal near, functional near (as the tasks involved simple discrimination) and sensory

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modality far (auditory/visual to cross-modal). Task format modality (response selection) was identical across training and transfer.

Kramer et al., (1995) used a dual-task paradigm to train monitoring of a changing display while responding to alphabet arithmetic items. The transfer tasks, also completed in a dual task format, were scheduling and paired associates running memory and were thus functionally different. Older adults did not differ from young adults in dual task costs after training and showed similar cost reductions with the transfer tasks. Transfer tasks were administered immediately after training was completed. The content dimensions for this study involved improvement in dual tasking skills which involves generalization, and the performance change for transfer assessed with speed and accuracy, and by costs, which did not differ from training. The classification is temporal near, functional far, and the modality was visual for training and transfer, therefore sensory modality near. Task format modality was near, consisting of response selection.

Transfer of Complex training—Using extended practice, Basak et al., (2008) trained older adults with a strategy based video game (*Rise of N ations*) for approximately 23 hours. Training produced improvement in transfer tasks including reasoning, task switching and working memory, visual short term memory, and mental rotation. The content areas of training are general strategies, the transfer assessments of performance based on speed and accuracy, as were the training assessments. Transfer testing took place shortly after training, thus the context transfer is temporal near, the tasks are far in the functional domain, and were visual, thus in the near sensory modality. Task format appears to be identical across training and transfer using response selection, thus near in that modality.

3.2. Temporal far studies

This section reviews studies in which there was a delay between training and testing of at least one month. Content transfer domains are only described if the study was not presented previously.

Transfer of Individual abilities: Memory, reasoning, UFOV—The strategy training approach of the ACTIVE trial did not show transfer immediately after training in mnemonics, reasoning or UFOV training. The ACTIVE trial was focused on general skills, and performance change assessments were of accuracy, the same as those trained for all three training conditions. Training effects on the tasks trained persisted for two years with booster sessions about 11 months after initial training (Ball et al., 2002) and were observed five years later (Willis et al., 2006). Thus for these two reports, there was temporal far transfer to the abilities tested, the transferred abilities were the same as trained, so they were functional near, and the same sensory and task format modalities of response selection were used, therefore modality transfer is near.

Derwinger, et al., (2005) followed up on the Derwinger et al., (2003) study of training strategics to recall four digit codes eight months later and found that those in the training groups maintained their performance. This study used a specific heuristic, the same assessment of accuracy for training and transfer, and was the only one reviewed here where subjects either received support or not for specific strategies. This represents temporal far

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transfer, functional near (same abilities) and the same sensory (visual) and recall task format modality, thus, modality near.

The UFOV paradigm shows both temporal far and functional far transfer in the Roenker et al., (2003) study. After 18 months, those receiving UFOV training maintained improved performance on the Road Sign Test administered in the driving simulator. As already described, the transfer to the testing modality was far. Training was also associated with fewer dangerous maneuvers such as forcing other drivers to avoid the car during a 14 mile drive (Roenker et al., 2003) after 18 months, though training did not affect driving errors immediately. The modality transfer was far, from visual training to multiple modalities, and format from response selection to assessment of driving errors.

Temporal far, functional far and modality far transfer were observed in the ACTIVE trial for three findings. Ball et al., (2002) reported that over two years, those receiving UFOV training retained improvements on the Timed IADL task, which is functionally and modality far. Wolinsky et al., (2006) reported that individuals in the UFOV training group showed less decline in responses to the SF-36, a health related quality of life measure, than in control subjects, indicating far functional and modality transfer over 24 months. Five years after training, those in the reasoning condition reported fewer IADL difficulties than those in the no-training control group, with far functional (strategy training to impairment in functional activities) and sensory (visual to multiple modalities) and task format modality (response selection to endorsement of IADL questions) transfer. (Willis et al., 2006).

Dual task training—Kramer et al., (1999) trained older adults on a cancelling and a tracking task and tested transfer with monitoring and alphabet arithmetic. The content dimensions for this study involved improvement in dual tasking skills, which involves some generalization, and the performance change for transfer assessed with speed and accuracy and costs, which did not differ from training. The reduction in dual task costs on the transfer tasks was observed approximately two months later. This represents temporal far, functional far, and sensory modality near (visual to visual) and task format modality (response selection the same) near transfer.

Transfer of complex training—A trial of multimodal strategy training used a combination of mnemonics, social training and goal management training with participants who had cognitive complaints. The content dimensions of the training were general, as the training involved cognitive, social, and planning skills, and the performance change of accuracy. The study showed temporal far transfer, with maintenance of some improvements over 3–6 months in recall (Craik et al., 2007). Recall had been trained as part of the multimodal approach; thus, transfer was functional near and test format modality near (recall to recall).

4. Discussion

This brief review shows that far transfer in aging studies does exist in the temporal, the functional, and the modality dimensions of context. The taxonomy of transfer developed by Barrett and Ceci, (2002) affords a systematic and relatively simple platform for assessing far

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transfer for studies on a wide range of abilities and types of training. The studies supported the existence of far transfer over time, over different functional contexts, and different sensory and test format modalities.

The content dimensions of the taxonomy predict the likelihood of observing transfer. Barnett and Ceci, (2002) suggested that more general approaches in training are more conducive to producing transfer than more specific ones. Although specificity as a training method within aging studies is defined somewhat more broadly than as defined by Barnett and Ceci, (2002), we can compare mnemonics training as conducted by Derwinger and colleagues (Derwinger et al., 2003; 2005), which is more specific than the training in the studies I have treated as complex and general, such as the multimodal training study (Winocur et al., 2007). Both the specific (Derwinger et al., 2005) and complex training (Winocur et al., 2007) are associated with far temporal transfer. Thus, relative specificity of training compared to that of more general or complex strategy training did not appear to reduce the probability of observing temporal far transfer effects in aging.

Although Barnett and Ceci, (2002) suggested that transfer is more likely to occur when the same performance change outcomes are used to measure the transfer, the aging literature suggests that transfer does occur with both more similar and very different types of assessments. The complex extended practice training offered in a strategy video game produced functional far transfer to attention, visual memory, reasoning, and spatial abilities (Basak et al., 2008). Dual task training produced temporal as well as functional far transfer (Kramer et al., 1999). Both of these studies involved similar performance change assessments. Yet in the ACTIVE trial, both reasoning and UFOV training showed transfer on change outcomes including fewer changes in health quality of life ratings (Wolinsky et al., 2006) and fewer increases in IADL outcomes (Willis et al., 2006) years after training.

There are also paradoxical results. It is clear that UFOV training, with considerable or with minimal strategy training, does not transfer to other *cognitive* abilities, (Ball et al., 2002; Edwards et al., 2005; Willis et al., 2006), even though it is thought to represent processing speed, a cognitive primitive. Yet UFOV training has also been shown immediately to transfer to the Timed IADL task in individuals with low UFOV performance at the beginning of training (Edwards et al., 2002; 2005). There is also some evidence that UFOV training may support maintenance of functional and modality far transfer effects, as UFOV training showed greater maintenance of reduced risk after 18 months in making dangerous maneuvers in driving compared to control groups (Roenker et al., 2003).

4.1. Extended practice versus specific strategy in memory outcomes

Nevertheless, the training of memory skills appears to be the one area in which extended practice training may be much more effective than specific strategy training in producing functional far transfer. Strategy training for memory alone does not produce functional or modality far transfer in the studies testing it (Ball et al., 2002; Willis et al., 2006), neither does complex strategy training (Craik et al., 2007). The two memory training studies showing functional far transfer (Jennings et al., 2005; Smith et al., 2009) used extended practice.

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The likelihood of observing transfer effects is related to the incorporation of training into performance during the transfer task, and the potential for strategy training studies to show transfer is likely to be affected by participants' compliance in applying memory strategies. This is an aspect of transfer that may be more important in aging studies but not in training young adults, as there may be an interaction between adult age, compliance, and individual differences in baseline memory abilities in transfer success. Here the problem is not whether the strategy can be retrieved, but whether it is *applied.*

It has been suggested that compliance is a problem with memory strategy training because it is effortful, requires retrieval of the mnemonic techniques trained, may require avoiding use of highly overlearned but ineffective encoding habits (Verhaghen and Marcoen, 1996), and is irrelevant to real world memory failures (Jennings et al., 2005). Lack of compliance may be also related to individual differences, as studies of memory training outcomes strongly suggest that those with less effective cognitive resources (e.g., Verhaeghen and Marcoen, 1996), poorer health, lower education, and lower self-efficacy (Bagwell and West, 2008) do not benefit as much from strategy training. In some cases trained participants may hardly benefit at all. In a method of loci training study, adults aged 75–101 showed small gains that did not increase beyond those observed early in training (Singer et al., 2003). Yet, in a study of retest effects of performance on reasoning, speed, and visual attention tasks (Yang et al., 2006), participants from the same population as the Singer et al. study did show practice-related improvements. In the ACTIVE trial, those with memory impairment defined as performance of 1.5 SD below the sample mean did not show gains in the memory training condition, although memory impaired individuals in the reasoning and speed of processing training showed training gains for those respective abilities (Unverzagt et al., 2007). This suggests that memory training, compared with other types of strategy training, may be uniquely ineffective in those who are most deficient in memory ability.

One of the difficulties that those who fail to improve in memory strategy training may experience is in being able to rely on cognitive control processes in retrieval of specific items in memory (e.g., McDaniel et al., 2007). For example, Rogers et al., (2000) trained young and old adults in a noun-pair recognition task in which a list of noun pairs is present in a lookup table at the top of a computer screen throughout training. A pair of nouns is presented in the center of the screen and the task is to determine whether that probe pair matches one of the pairs in the lookup table. The task can be completed accurately by either scanning the noun pairs in the table or directly retrieving them from memory. Direct retrieval, is, of course, more efficient, and in the Rogers et al., study, more than half of the older adults transitioned to direct retrieval. However, even after hundreds of repetitions of the same pairs in the lookup lists, the remainder of the older adults did not switch from scanning to direct retrieval with practice. In this study, Rogers et al. also observed a significant relationship between associative memory abilities and the transition to the direct retrieval strategy over practice, suggesting that those who were successful learners were better able to use the retrieval strategy. Hertzog et al., (2007) additionally found that the older adults' deficit in shifting to direct retrieval is partly due to underestimation of the difference between the amount of time it takes to retrieve directly and the amount of time it takes to scan, an important cue to the perception that direct retrieval is more efficient. Other

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reasons they cited for the deficit in transitioning to direct retrieval may include willingness to use suboptimal strategies, and poor memory self-concept (see also West et al., 2008). These deficits may have important functional consequences for strategy training: they may affect self regulation of conscious strategic activities in memory retrieval.

The extended practice approach in memory training, by contrast, trains discrimination of information and gradually increases task difficulty as discrimination improves (Jennings et al., 2005; Smith et al., 2008). This may facilitate training of retrieval abilities by reducing the difficulties that strategy application engenders: by using gradual increases of difficulty, the task is less effortful, retrieval requirements for strategies are reduced because of increased discrimination between items, and suboptimal encoding habits can be bypassed. Thus, extended practice training may require less self regulation in retrieval than strategy training.

4.2. How does extended practice produce far transfer?

In some ways, it is surprising that extended practice can produce far transfer, as it may be thought to involve more specific skills than strategy use. However, there appear to be several key factors common to the extended practice studies showing transfer.

By definition, extended practice studies involve considerable repetition of the skill to be trained. Because items are assessed individually in extended practice studies, it is relatively easy to quantify the amount of direct experience in using the cognitive skills that participants have while training, in contrast to studies training general strategies, which involve less protracted individual practice over numerous trials. That is, practice in strategy studies does not typically involve continuous performance of the ability during the training session; whereas performance in extended practice training is likely to be over many more individual trials. For example, training in the study by Jennings and colleagues, (2005) was for over 6 hours, or approximately 1464 trials. The training used for UFOV varies as it is criteria based but ranges from over 300 trials to 3000, with an average of 1040 trials in an average training time of 4.5 hours (e.g. Roenker et al., 2003). Other studies with successful functional far transfer have used considerably longer times for training than most strategy training studies; Smith et al., (2009) provided 40 hours of training. For very complex tasks, the duration of practice may need to exceed a specific threshold before transfer becomes apparent, as Basak and colleagues, (2008) found that many of the effects they observed did not manifest in the outcomes of their participants even with 10 hours of training; significant transfer effects were observed after 23 hours. Thus, extended practice may involve much more experience using the skill, and practice based processing changes may facilitate generalization in transfer.

Adaptive approaches may also be important in extended practice training. Studies using individualized progression in skill learning included the UFOV task (see Ball et al., 2007), lagged recognition, (Jennings et al., 2005), auditory processing training (Smith et al., 2008), and video gaming (Basak et al., in press). A related principle is that the training remains challenging, yet not overwhelmingly difficult. Jennings and Jacoby (2003) found improvement in performance by systematically increasing the lags between identical items up to 28 and maintaining task difficulty by requiring accurate performance for several trials

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before increasing lags. The auditory processing training approach of the IMPACT study kept performance at approximately 85% correct at a given level, assuring that ceiling effects were not reached (Smith et al., 2009).

Gopher, (2007) suggests that training of processes in a speeded complex task with multiple attentional demands such as driving produces better learning if the training involves variable emphasis on different components of the task rather than training on individual components in blocked presentations. This holistic approach to training of demanding tasks requires that participants cope with all of the components of the task simultaneously. This may encourage generalization of skills across multiple subprocesses. Kramer et al., (1995) also found that using a variable priority approach to dual task performance, whereby participants were instructed on which task to prioritize across trials produced better performance than fixed priority instructions. Bherer et al., (2005) showed that variable priority training did not enhance performance on easy visual and auditory discrimination tasks over fixed priority, suggesting that variable emphasis is more beneficial for difficult tasks.

4.3. Subjective appraisals and transfer

Barnett and Ceci's, (2002) transfer framework applies to objective assessment of transfer of trained skills and I have shown its utility in aging research. However, the framework does not apply readily to the user's subjective appraisal of the *consequences* of successful transfer. Participants may report changes in self reported dimensions of cognitive behavior, such as fewer failures, or in affective dimensions, such as reduced frustration with failures, or greater confidence in everyday remembering. Such outcomes are important in aging research because how participants feel about their cognitive functioning and health related quality of life after a training intervention, when appropriately measured, can reliably indicate the effect of training the skill on their broad physical, social, and emotional functioning, which in turn, are associated with the ability to remain independent (see, e.g., Wolinsky et al., 2006). Several of the training studies in aging have evaluated subjective measures of performance in everyday situations, and of affective or coping responses to cognitive failures.

Participants in the IMPACT study training had more positive subjective appraisals of everyday cognitive performance than control participants, who watched educational materials on a computer (an approximation of the idea that general mental stimulation promotes memory skills (Smith et al., 2009). Van Hooren et al., (2007) recruited participants with cognitive complaints into a goal management training intervention or a wait list control group. Goal management training involves training participants to improve their planning and structuring of intentions. The steps of goal management training are to "stop" and assess goals, select the appropriate goals and organize them into subgoals as necessary and compare the outcome of the actions taken with the goals to be achieved. Immediately after training, there was transfer to a measure of (reduced) annoyance when cognitive failures occurred. The training was also associated in a reduction in anxiety over 7 weeks in the trained compared to the control subjects. In the multimodal training study, participants improved in self reports of negative ways of coping six months after training (Winocur et

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al., 2007). They also gave themselves better self ratings on a questionnaire about everyday executive functioning (Levine et al., 2007) after 3–6 months.

4.4. Improving measurement of transfer

The ACTIVE study was the first to test directly whether cognitive interventions improve everyday functional abilities (Jobe et al., 2001). If the main goal of cognitive training is to improve functional outcome, how such outcomes are measured is paramount. The furthest transfer effects may be phenomena with low base rate occurrences, so the power to detect differences between groups is much lower than for the skill trained. Assessments of behavioral competence in older adults, such as IADL scales, may be good predictors of ability to remain independent, but they measure impairment rather than a range of ability. In addition IADLs are not specifically designed to assess impairment in activities of daily living relevant to specific cognitive abilities and deficits may be attributable to multiple noncognitive sources, including visual impairments.

Using low base rate outcome measures additionally requires that the appropriate analytic techniques must be used, such as changes in hazard/survival rates as a function of training rather than mean scores on tests, which is the current practice (e.g., Willis et al., 2006; Ball et al., 2007). However, these methods are rarely used in cognitive aging studies and they require samples numbering in the thousands with very long term follow ups.

The few efforts to develop everyday outcome measures that simulate everyday activities such as the Timed IADL test (Edwards et al., 2005) and the Road Sign test (Roenker et al., 2003) have face validity and predictive validity with respect to the involvement of rapid processing of information in everyday tasks but the variety and complexity of content that could be used to assess everyday functional ability have not been as thoroughly researched, as say, the content of items in IQ tests. It is likely that the depth and breadth of effort used to develop the items used in measures of IQ must be applied to develop the content of measurements of everyday function so that it adequately indexes a wide range of levels of competence.

The principles of measurement of everyday function are also important. In the fields of education and of health, item response theory (IRT) has been used as the theoretical basis of test development, although psychology has lagged behind in continuing to use classical test theory (Embretson and Hershberger, 1999). IRT, also known as latent trait theory, uses a model of measurement whereby levels of a given trait are assessed by the ability level of the test taker and the properties of the items, among which is item difficulty (see also Bond and Fox, 2001). The Rasch model, which is the simplest IRT model, assumes that the latent trait is unidimensional; the difficulty of items is consistent with ability such that correct scores on more difficult items reflect greater ability and more difficult items have a lower probability of being correctly answered than less difficult ones, independent of person ability. It also assumes that individuals with greater levels of ability will be more likely to score correct on more items. They have a higher probability of correctly answering any items, independent of item difficulty, than those with low ability (Wright and Stone, 1979).

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Computer adaptive testing is a good example of IRT in psychometric measurement. The Graduate Record Examination, for example, uses IRT to determine the test takers' ability based on the probability of correct responses to items for which different levels of ability have been established. Because the same construct is assessed, the properties of the items, not their content, determine the ability level of the test taker on the construct. In principle, this could mean that the full range of ability can be assessed without floor or ceiling effects. Because computer adaptive testing targets the level of participants' ability based on the probability of their success on the items, individuals at different levels of ability may not complete any of the same items on a specific test, and yet their ability is measured accurately. For example, in financial matters, different respondents could be assessed on a range of skills relating to different levels of hypothesized ability: being able to count change, to balance a checkbook, to use information from multiple financial statements, to make sound decisions about short-term investment strategies, or to use appropriate strategies in long-term planning for retirement. The flexibility in adaptive assessment additionally reduces participant burden, because relatively few items need to be included in the assessment. The use of IRT measures in aging outcomes has been virtually unknown outside of some studies of ability. However, it is clear that this approach will be extremely useful in creating measures of functional ability that apply to individuals at every level of performance. It can provide a powerful platform to assess transfer effects on functional far outcomes in many areas of everyday life.

In sum, I have shown that far transfer occurs for both strategy and extended practice training approaches. There is an interaction between the skills trained and the efficacy of strategy training with respect to transfer, with only temporal far transfer for memory but functional far and modality far transfer for other abilities studied. Strategy training may not produce functional far transfer in memory because older adults may experience deficits in self regulation in strategy application or other aspects of cognitive control, poor memory self-efficacy, or use of suboptimal approaches to retrieve information. These problems may be circumvented by using adaptive extended practice training. The effects of complex training, such as video gaming, to improve memory has not been tested, although work by Basak and her colleagues, (2008) shows that it transfers to improvement in attentional and other cognitive functions in older adults. There is thus real promise that training can transfer to improved functioning in different cognitive abilities in older adults. Better measurement of everyday outcomes will be critical to determining whether training can produce transfer to increased or maintained competence in functional abilities.

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Table 1

A taxonomy of transfer with transfer effects seen in aging studies

Temporal near			Temporal far			
Functional near	**Functional far**		**Functional near**		**Functional far**	
Modality far	**Modality near**	**Modality far**	**Modality near**	**Modality far**	**Modality near**	**Modality far**
Individual ability training						
	Jennings et al., (2005)	Smith et al., (2009)	Ball et al., (2002)			Roenker et al., (2003)
	Immediate	Immediate	2yrs			18 months delay
	Lagged recognition to n-back, pointing, source recognition	Memory to neuropsychological memory & working memory tasks	Same trained and transferred			UFOV to Road Sign
	Visual to visual	Auditory to auditauditory Recognition to recall	Visual to visual			Visual to visual
	Recognition to recognition		Response selection to response selection			Response selection to turning and braking
		Roenker et al., (2003)	Willis et al., (2006)			Roenker et al., (2003)
		immediate	5 yrs			18 months delay
		UFOV to Road Sign	Same trained and transferred			UFOV to driving
		Visual to visual	Visual to visual			Visual to multiple
		Response selection to turning and braking	Response selection to response selection			Response selection to turning and braking
		Edwards et al., (2005)	Derwinger et al. (2005)			Ball et al., (2002)
		immediate	8 months delayed			2 yrs delayed
		UFOV to Timed IADL	Same trained and transferred			UFOV to Timed IADL
		Visual to visual	Visual to visual			Visual to multiple
		Response selection to multiple, including manual manipulation	Recall to recall			Response selection to multiple, including manual manipulation Wolinsky, et al., 2006) 2 yrs delayed UFOV to SF36 Vsual to multiple Response selection to ratings Willis et al., (2006)

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Temporal near			Temporal far			
Functional near	**Functional far**		**Functional near**		**Functional far**	
Modality far	**Modality near**	**Modality far**	**Modality near**	**Modality far**	**Modality near**	**Modality far**
						5 yrs Reasoning to IADLs Visual to multiple Response selection to endorsement of impairments
Dual TaskTraining						
Bherer et al., (2005)	Kramer, et al., (1995)				Kramer et al., (1999)	
Immediate	Immediate				2 months delayed	
Discrimination to discrimination	alpha arithmetic and monitoring to paired associates and scheduling				Cancelling and tracking to monitoring and alpha arithmetic,	
Auditory to visual	Visual to visual				Visual to visual	
Response selection to response selection	Response selection to response selection				Response selection to response selection	
Complex training						
	Basak et al., (2008)		Craik et al., (2007)			
	Immediate		3–6 months delayed			
	video game to four supervisory abilities Visual to visual		Recall strategies to recall			
	Response selection to response selection		Multiple to multiple Recall to recall			