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What's cooking? – Cognitive training of executive function in the elderly

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Executive function involves the efficient and adaptive engagement of the control processes of updating, shifting, and inhibition (Miyake, 2000) to guide behavior toward a goal. It is associated with decrements in many other cognitive functions due to aging (West, 1996; Raz, 2000) with itself particularly vulnerable to the effect of aging (Treitz et al., 2007). Cognitive training in the form of structural experience with executive coordination demands exhibited effective enhancement in the elderly (Hertzog et al., 2008). The current study was thus aimed at the development and evaluation of a training regime for executive function in the elderly. The breakfast cooking task of Craik and Bialystok (2006) was adapted into a multitasking training task in a session (pre-test vs. post-test) by group (control vs. training). In the training condition, participants constantly switched, updated, and planned in order to control the cooking of several foods and concurrently performed a table setting secondary task. Training gains were exhibited on task related measures. Transfer effect was selectively observed on the letter–number sequencing and digit symbol coding test. The cooking training produced short term increase in the efficiency of executive control processing. These effects were interpreted in terms of the process overlap between the training and the transfer tasks.

Keywords: executive function, cognitive training, cognitive aging, digit symbol coding

INTRODUCTION

Aging results in general declines in cognitive performance (McDowd et al., 2000; Salthouse et al., 2003; Lemke and Zimprich, 2005; Levitt et al., 2006; Finkel et al., 2007). The declining trend begins for adults in their 20 s and accelerates at age 50 for product measures of intelligence or fluid intelligence (measures reflecting the efficiency of processing; Salthouse, 2004, 2006). Despite the profound effect of aging on cognitive performance, considerable variation in cognitive performance is still clearly observed at all ages (Salthouse, 2006). These individual differences raise the possibility that specific types of activities may contribute to enhanced cognition.

Hertzog et al. (2008) reviewed evidence on cognitive enhancement and concluded that lifestyle and cognitive training (in addition to physical activity) play critical roles in the maintenance of cognitive functions. The idea that keeping mentally active helps maintain one's cognitive functioning is also known as the "use it or lose it" hypothesis, though the hypothesis is much better received by the general public than academia. Novel and challenging cognitive activities, such as Sudoku, Mahjong, and learning a foreign language or a musical instrument, have been suggested to mitigate age-related cognitive declines. Undoubtedly, older adults are capable of learning new cognitive tasks. The controversy of the "use it or lose it" hypothesis is whether new learning experiences are transferable to other cognitive tasks (Ackerman et al., 2010).

In general, cognitive training does not easily transfer, and when it does, near transfer is much more often observed than far transfer (Green and Bavelier, 2008; Hertzog et al., 2008; Ackerman et al., 2010). In near transfer, the effect of learning is transferred to tasks that share high degrees of surface and deep similarity with the training task. For example, if a working memory training regime adopted a spatial 2-back training task, then transfer performance on 3-back or numerical 2-back tasks could be considered examples of near transfer because the transfer task shares surface and deep processing requirements with the training task. In contrast, transfer performance on an operation span task may constitute far transfer because of the lack of any surface similarity between the transfer and learning task (Thorell et al., 2009).

Despite the difficulty, the demonstration of far transfer is highly desirable because transferring the learning experience to non-trained tasks or non-targeted performances is the premise of the "use it or lose it" hypothesis that motivates the practice and research of cognitive intervention. Therefore, there is enormous interest in learning about the conditions for successful far transfer in cognitive training. Hertzog et al. (2008) suggested that executive functioning training, working memory training, and metacognitively oriented interventions produced more satisfactory transfers in this respect. Rather than focusing on micro-level processes and task-specific strategies, these training regimes targeted mechanisms used by individuals to exert cognitive controls in multiple task contexts, which could be directly related to their relatively successful transfer performance.

The current study focuses on executive function training, mainly because of its applicability in multiple task contexts, which is likely to result in better transfer performance. A second, not entirely independent, reason for focusing on executive function training is related to the strong connection between executive and daily functioning in older adults. Executive function is mainly supported by the prefrontal cortex, which experiences earlier and greater degrees of decline with advancing age (Raz, 2000). Thus, executive control functions are more susceptible to the effects of aging than cognitive functions supported by other brain regions (West, 1996; Raz, 2000; Treitz et al., 2007). Indeed, executive dysfunction was a strong predictor of functional impairment in the elderly living in communities or assisted-living facilities (Grigsby et al., 1998; Cahn-Weiner et al., 2000; Burdick et al., 2005). Intervention that targets executive functioning is thus likely to directly link to the daily functioning of the elderly.

Despite the important adaptive roles of executive functioning for the elderly, the definition, and measurement of executive functioning in the literature is imprecise and has varied among researchers (Salthouse et al., 2003; Holtzer et al., 2005; McCabe et al., 2010). In general, executive functioning refers to the planning and control of goal-directed thoughts and actions. Executive functioning is achieved by a system of control processes that gage the flow of information to execute specific behavioral goals (Banich, 2009). Three frequently studied executive control processes include shifting (switching back and forth between tasks and mental sets), updating (monitoring and updating information according to the relevance of tasks), and inhibition (inhibiting dominant but inappropriate responses; Miyake, 2000; Friedman et al., 2008). Working memory and inhibitory control, for example, are important functions of these processes (Thorell et al., 2009).

Contexts that typically recruit such executive control functions are situations that require coordination between multiple tasks, such as dual-tasking or multitasking. The elderly suffer larger dual-task costs than young adults, and the cost is greater than age-related slowing can predict (Verhaeghen et al., 2003). Training that targets dual-task performance has been found to be effective for the elderly (Kramer et al., 1995). Kramer et al. (1999) trained both young and older adults on dual-tasks with either a fixed-priority or variable-priority regimen. Participants were asked to treat the two tasks with equal importance in the former condition and to constantly vary their priority over the two tasks in the latter condition. The authors found that the older adults' dual-task performance improved with training and transferred to the untrained condition. More interestingly, age-related, dual-task performance differences between older and younger adults were reduced substantially for participants trained under the variable-priority condition. In a similar vein, older adults trained on a strategy-based, real-time video game also exhibited far transfer to executive function tasks, such as n-back, task switching (Basak et al., 2008).

Thus, the current study adopted a multitasking training task in which participants were required to strategically shift between task goals to achieve maximal performance. In addition, the task took the form of a daily activity to increase the likelihood that the strategies learned in this task would be retrieved and rehearsed in daily settings. The current training task was adapted from the breakfast cooking task of Craik and Bialystok (2006). Participants controlled the cooking times of various foods on a computer screen so that each food was cooked for exactly the pre-set cooking time. All foods were to be ready at the same time. Participants were also asked to engage in a table setting secondary task concurrently with the cooking primary task. The training progressed in a zigzag manner from the slowest to fastest pace with two levels of complexity. Participants were provided with feedbacks on their performance at the end of each training trial. They were also required to meet passing criteria on the training task before they could progress to the next training trial.

Craik and Bialystok's (2006) breakfast task yielded several measures of multitasking and executive control. The *disparity* is the absolute difference between the time spent on cooking a food and its ideal cooking time; disparity relies heavily on prospective memory. Low disparity is supported by the successful monitoring of the progress of each food, maintenance of this information and task goal when conducting the other sub-task (e.g., table setting) and the timely switching between sub-tasks (e.g., table setting, monitoring the progress of other foods). The *range* of stop times refers to the difference between the stop times for cooking the first and the last food. The range reflects the degree to which participants account for the difference in cooking times across foods to plan the start and stop times of all foods. Range is mainly a measure of global planning and, to some extent, the use of working memory to retain the overall plan throughout the task (Craik and Bialystok, 2006). Craik and Bialystok (2006) found age-related decline in both disparity and range performance.

The current study adapted the breakfast cooking task into a training task. The specific functional aspects of executive control trained and examined using this task were prospective memory (as reflected on discrepancy) and planning (as reflected on range). In the breakfast cooking task, participants have to hold the status information of each dish in working memory. These information are important to the execution of cooking plans (i.e., decide when to start and stop cooking the next food) and to the decisions of switching back from the table setting sub-task when necessary. Participants have to constantly update the content and the ordering (priority) these information due to continuous alternation in themselves and contextual relevance (e.g., foods that are nearer to their starting/stopping times require closer monitoring or attention than other foods). In addition to cooking status information, participants maintain, and update the priority of different task goal information (i.e., the start and stop of each food according to its pre-set cooking time, have all foods ready simultaneously, set as many tables as possible). For example, at the beginning of a cooking session, the priority is given to the goal of arranging cooking schedule so that all foods are simultaneously ready. When there is some time left before the cooked foods is to be stopped and/or before new dishes is to be started, the priority is given to table setting. When participants are setting the table, the goal of having each food cooked to its ideal cooking time is maintained. As a whole, the cooking training task constantly engages the participants in the maintenance, updating, and switching between two sets of information (i.e., cooking status and task goals).

Other than the updating and set switching training that participants received from the cooking primary task, they also receives practice on the shifting between the cooking primary task and the table setting secondary task. The information related to the cooking task is located at the right half of the display. Participants click on the start and stop buttons according to the progress of cooking.

The table setting display was located on the left and the participant drags the dishware to its location in order to set the four places in a table. Participants make the shifting decisions according to the task context.

The cooking training was expected to result in improved prospective memory and planning performance on the task. Disparity and range served as measures of training task gains and were expected to reduce with the progression of training trials. The three working memory test measures in WAIS-III, including digit span (the backward span), arithmetic, and letter–number sequencing, were adopted to evaluate transfer effects. They were adopted since working memory supported the prospective memory and planning functions trained by the cooking task in a general sense (Burgess et al., 2005; West and Bowry, 2005; Reynolds et al., 2009; Brewer et al., 2010). Also, these WAIS sub-tests do not share any surface similarity with the current training task, which enables them to serve as valid measures of far transfer. More important, these three tests differ in their overlaps with the executive control processing recruited by the training task that yielded differential predictions of their transfer effects.

The three measures differ in terms of their overlaps in the demanded processing with the cooking training task. The letter–number sequencing test presented a series of numbers and letters in random order. The participant repeats back the numbers in order first followed by the letters in alphabetical order. This task thus shares with the cooking task strong demands of maintenance and updating (re-ordering) as well as constant switch between two different sets of information (Emery et al., 2007). Good training transfer on the letter–number sequencing test was predicted based on these shared processing demands (Dahlin et al., 2009).

The arithmetic test auditorily presented arithmetic word problems with increasing difficulty. Participants respond on the basis of their mental calculation. As they are mentally calculating the answer, participants maintain, and update series of numerals as well as shift among the tasks of addition, subtraction, multiplication, and division for different problems. The arithmetic test, however, deviates from the cooking training in the lack of consistent set switching (between different types of information) within the same problem (task). Thus, the training transfer observed on the arithmetic test, if any, is expected to be smaller than that in the letter–number sequencing test. In the digit span test, the forward or the backward digit span measures the number of digits the participant correctly repeats in their presentation order or in backward orders. The backward span recruits the updating process but it does not involve set switching between two different types of information. The process overlap between the backward span and the cooking training task was thus also limited compared to the letter–number sequencing test. Its transfer effect could be even smaller than the arithmetic test since the latter recruits the shifting process that is partly shared by the training task while the backward span does not. In summary, based on the differential degrees of process overlap with the training task, it is predicted that greater transfer should be observed on the letter–number sequencing test than the arithmetic or backward span test, while the arithmetic test may also exhibit stronger transfer than the backward span.

Measures of processing speed in the WAIS-III, including digit symbol coding and symbol search, are also included in the transfer measures. Transfer effects were, however, not expected for these measures because the cooking training task is expected to yield specific improvements on executive function related measures, not processing speed related ones.

MATERIALS AND METHODS

PARTICIPANTS

Participants were 57 healthy, community-dwelling older adults with 31 of them participating in the training condition and 26 in the control condition. Their educational backgrounds varied from none to the graduate level, but all lived independently and functioned successfully. Participants completed a self-report questionnaire with their age, education, health condition, working experience, and daily activities. Those with histories of significant medical, psychiatric, or neurological problems were not eligible for the study.

Four of the training participants did not finish and data was lost for one other participant, resulting in 26 valid participants in the training condition (9 males, 17 females, age: 56 ~ 79). Data from the valid training participants were tested for differences in baseline performance and biographical variables from the control participants (8 males, 18 females, age: 56 ~ 84). Results of these tests as well as the mean age, years of education/working, and pre-training performance on the WAIS-III digit span, arithmetic, letter–number sequencing, digit symbol coding, and symbol search sub-tests were listed in **Table 1**.

Participants of the training and control groups underwent different recruiting procedures, although all were compensated for their participation with cash and/or small gifts. Training

Table 1 | Demographic and pre-training performance levels of the control and training participants.

	Control ($n = 26$)		Training ($n = 26$)		
	M	**SD**	***M***	**SD**	***p***
Age	65.5	7.4	62.9	5.6	0.16
Years of education	11.8	5.5	12.1	4.2	0.82
Years of working	31.4[d]	9.3	25.2[e]	12.6	0.07
MMSE	28.1[c]	2.0	28.6	1.4	0.35
Digit span	9.3	2.7	10.7	2.5	0.07
Forward	10.6[a]	2.6	11.6	2.7	0.19
Backward	5.2[a]	2.0	6.1	1.8	0.10
Arithmetic	9.5[b]	2.4	10.2[a]	3.3	0.40
Letter–number sequencing	9.5	3.4	10.3	3.4	0.42
Digit symbol coding	11.0	3.3	12.6	2.2	0.04
Symbol search	10.4	2.6	11.7	2.3	0.06

Mean and SDs of digit span, arithmetic, letter–number sequencing, symbol search, and digit symbol coding are based on WAIS scaled scores. Forward and backward digit span are raw scores.

[a] One missing observation.

[b] Two missing observations.

[c] Four missing observations.

[d] Five six missing observations.

[e] Six missing observations.

participants were recruited for a "cognitive training" study and were informed that the study might benefit their daily cognitive functioning. Participants of the control groups also participated in other studies in our lab that administered a similar set of tests. They were recruited if they were willing to return for a post-test after 6 weeks (they were not informed of their status as the control group for this study).

DESIGN AND MATERIALS

The study was a group (training vs. control) × session (pre-test vs. post-test) mixed design, with group serving as a between-subject factor and with session serving as a within-subject factor.

The training task was adapted from Craik and Bialystok's (2006) breakfast cooking task. Participants cooked four or six foods and set as many tables as possible while maintaining the specified performance goals. They were informed that their primary goal was to cook each dish for the specified duration and to get all dishes ready at the same time. As a secondary task, they were also instructed to set as many dining tables as possible.

For the four-dish training condition, the dishes were stir-fried water celery, eggs with green onion, sautéed bean curds, and sautéed green onion with beef. Lemon fish and clam soup were included for the six-dish training condition (see **Figure 1**). The specified cooking times for these foods varied (1.5, 2.5, 3, 4, 5, and 6 min). Participants controlled the start and stop of each dish by clicking on a corresponding button located on the top and bottom of the pictures of each food. A timer in the form of a vertical scale marked in minutes was located beneath the pictures and the start/stop buttons (see **Figure 1**). As the start button was pressed, the timer turned red and rose incrementally in height to indicate the time. There were not any additional cues for when to stop cooking each food. For overcooked foods, the scale kept increasing until it reached the scale maximum, which was 6 min. As a whole, the participant determined and monitored the beginning and end of the cooking of each food to have all the foods simultaneously ready. In the table setting task, participants clicked and selected one item from the bowls, plates, chopsticks, spoons, and cups at the bottom of the table (see **Figure 1**) and dragged it to the appropriate location until all four places on the table were

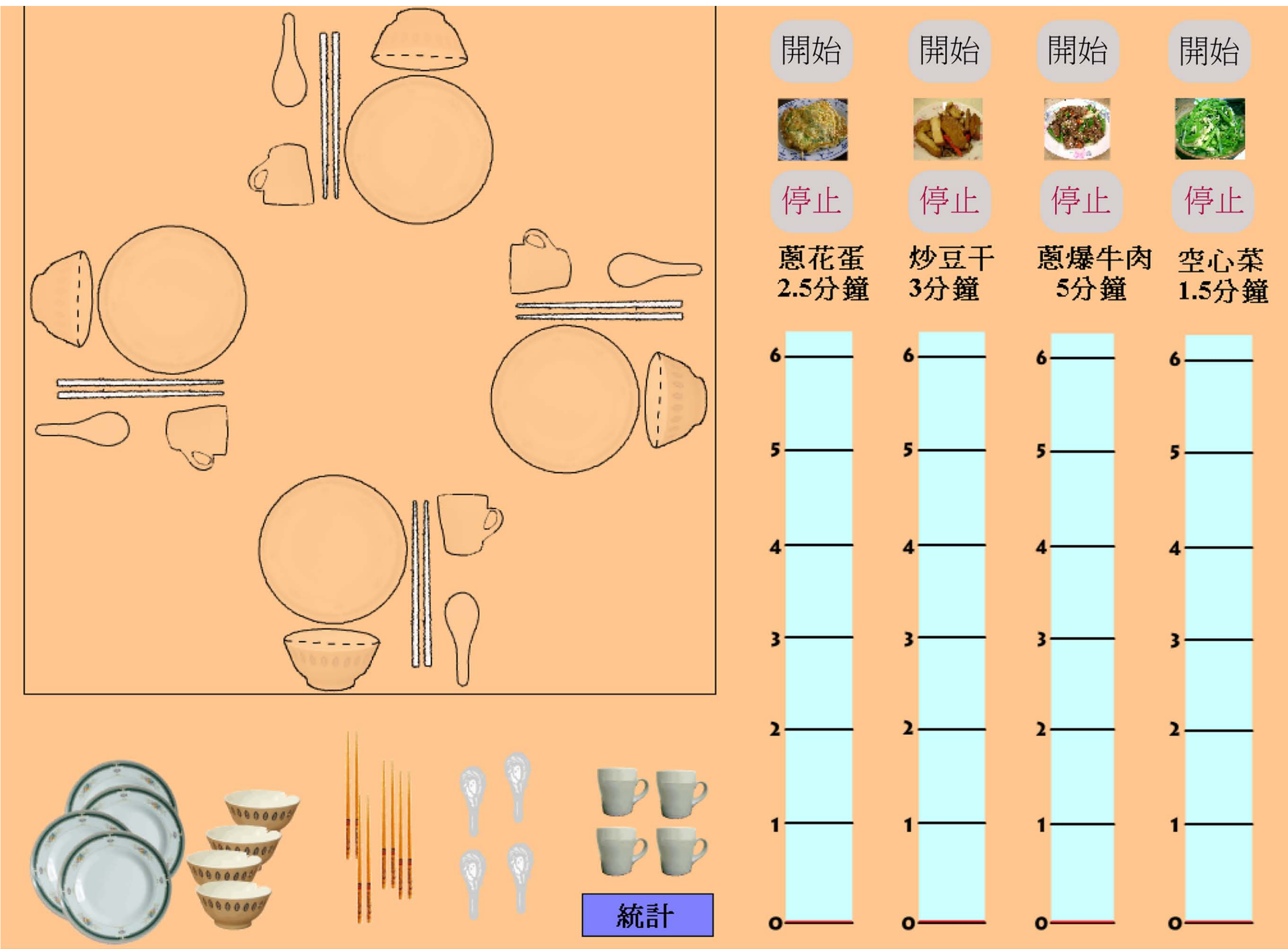

FIGURE 1 | Illustration of the training task screen. Right: cooking was the primary task. Participants controlled the start and stop time of cooking. Left: table setting was the secondary task. Participants moved the dinnerware to their respective locations in the four places.

set. Participants clicked the "next" button at the bottom right of the table to clear the setting and to start with a new table setting trial.

The training task was divided into five levels of speed by varying the speed of the timer, with I–V representing the slowest to the fastest. In each of the five training sessions, participants performed two training trials that differed in speed: "practice, I," "I, II," "II, III," "III, IV," and "IV, V." Task complexity (i.e., numbers of dishes) varied within each session. The numbers of dishes were "2, 4," "4, 6," "6, 4," "4, 6," and "6, 4" for the five sessions[1]. At the end of each training trial, participants were informed about whether they successfully passed. They were also given feedbacks by the experimenter about their performance on discrepancy, and range and table setting if the participant produced inconsistent performances on these measures. In the latter case, the experimenter would reiterate the primary and secondary task goals and ask the participants to maintain reasonable performance on all tasks. The passing criterion was mainly based on discrepancy. Discrepancy should not exceed one unit on the time scale and the real-time for the unit varied from 40 to 5 s depending on the speed. However, the participant would not be able to pass the training run if they were highly deviated on the range measure or the number of table set (e.g., when they were ignoring the secondary task). Participants who failed a training run were requested to repeat until they met the passing criterion. The repetition was terminated for participants who repeated five times or who refused to repeat any more. In such cases, the best performance on range and discrepancy was recorded.

APPARATUS AND PROCEDURE

The training task was written in Flash 8.0. The presentation and response collection was controlled by an IBM Pentium 4 notebook. The participants' control over the cooking task, according to their preference, involved either a mouse or a graphic tablet (Wacom CTE 650). Participants of the training condition participated in five training sessions and two testing sessions (pre-test and post-test). Control participants only underwent the two testing sessions. In both testing sessions, participants were administered the MMSE and the WAIS-III digit span, arithmetic, letter–number sequencing, digit symbol coding, and symbol search sub-tests. They also completed a background questionnaire in the first session. The training sessions spanned 5 weeks with one session each week. Each of the testing sessions lasted around 1 h, and the training session lasted for about 30 min to an hour. The training sessions were either conducted in a room at the community college where the participant attended or in an activity room in the community where the participant lived.

In the first training session, participants were informed that the training concerned executive functioning, including the ability to shift among tasks, update incoming information, and inhibit irrelevant information – all of which are critically relevant to one's daily activities. They started with a practice trial (two dishes) and were instructed that their primary goal was to cook each food for the specified duration and to have all of the foods ready at the same time. They were also instructed to set as many tables as possible, concurrently with the cooking task. However, it was made clear to participants that the primary task was cooking and that table setting was the secondary task. They started with the practice trial, where they were allowed to stop and repeat at any point to familiarize themselves with the procedure. In each subsequent session, participants received further instructions on the procedure of the training task and performed a brief practice trial using a training trial from a previous session that was no longer going to be presented.

Participants also received training instructions on the planning of cooking schedules to have all foods completed at the same time in the first 2 weeks. This instruction was delivered before the start of the training trial by asking participants how they would order the start of each food. A discussion on how and why dishes of different cooking times are ordered followed this question if the participant could not generate an optimal plan. The training instruction was also given in subsequent weeks if the participant failed a training run.

The five transfer tests were administered following the standard procedure in WAIS-III (Taiwanese version). In the digit span test, participants repeated a series of orally presented digits in forward or backward order. In the arithmetic test, participants responded to orally presented mental arithmetic problems. In the letter–number sequencing test, participants sequentially ordered a series of digits and Chinese zodiac animal names. In the digit symbol coding test, participants referred to a code table for matching symbols according to the digit presented in each item. Next, they drew the matching symbol for the digit. In the symbol search test, participants examined two symbols presented on the left and then responded to whether these symbols appeared in a group of five symbols on the right.

RESULTS AND DISCUSSION

BACKGROUND MEASURES

Control and training participants were tested for their match in mean age, years of education, and gender as well as their baseline performance on the MMSE, arithmetic, and letter–number sequencing. However, significant and marginally significant differences were observed on digit symbol coding, symbol search, and digit span performances (see **Table 1**). ANCOVA was thus performed in subsequent analysis of training transfer using the baseline test performance as the respective covariate.

TRAINING EFFECTS – TRAINING TASK PERFORMANCE

The discrepancy measure was the mean discrepancy between the time allowed and the time taken to prepare a food. Range was adjusted according to the number of foods since the difference between the first and the last stopping times was affected by the number of foods that needed to be stopped. The range measure was adjusted by dividing by three or five, depending on whether the trial was for four or six foods. z Scores for

[1]Task complexity was determined adaptively for the first 7 participants but was arranged in fixed orders for the 19 participants who were subsequently trained. This modification in training protocol was made to facilitate the analysis of the training performance. For the 7 participants, the arrangement of the timer speeds was the same as the other 19 participants. The complexity of the training trials (as defined by the number of dishes) was adapted according to performance on the immediately previous training trial.

the discrepancy and range measures were also computed. The adjusted range and discrepancy as well as their *z* scores were further averaged across training trials of similar speed and complexity, i.e., 1–2, 3–4, 5–6, 7–8, 9, to reduce fluctuations in the data. **Figure 2** showed that both range and discrepancy decreased across trials. One-way ANOVA treating training trials (1–2, 3–4, 5–6, 7–8, 9) as a within-subject factor was performed on discrepancy, range as well as their *z* scores. The training trials had significant effects on range [$F(4,100) = 2.99$, $p < 0.05, \eta^2 = 0.04$; the respective means were 10.01, 5.61, 7.01, 2.87, 4.80], *z* score of range [$F(4,100) = 15.45$, $p < 0.0001, \eta^2 = 0.38$; the respective means were 0.56, 0.16, 0.00, −0.47, −0.71], discrepancy [$F(4,100) = 6.87$, $p < 0.0001, \eta^2 = 0.13$; the respective means were 15.06, 19.65, 20.29, 17.50, 5.45] and *z* score of discrepancy [$F(4, 100) = 5.75$, $p < 0.0005, \eta^2 = 0.18$; the respective means were 0.16, 0.25, 0.13, −0.10, −0.76].

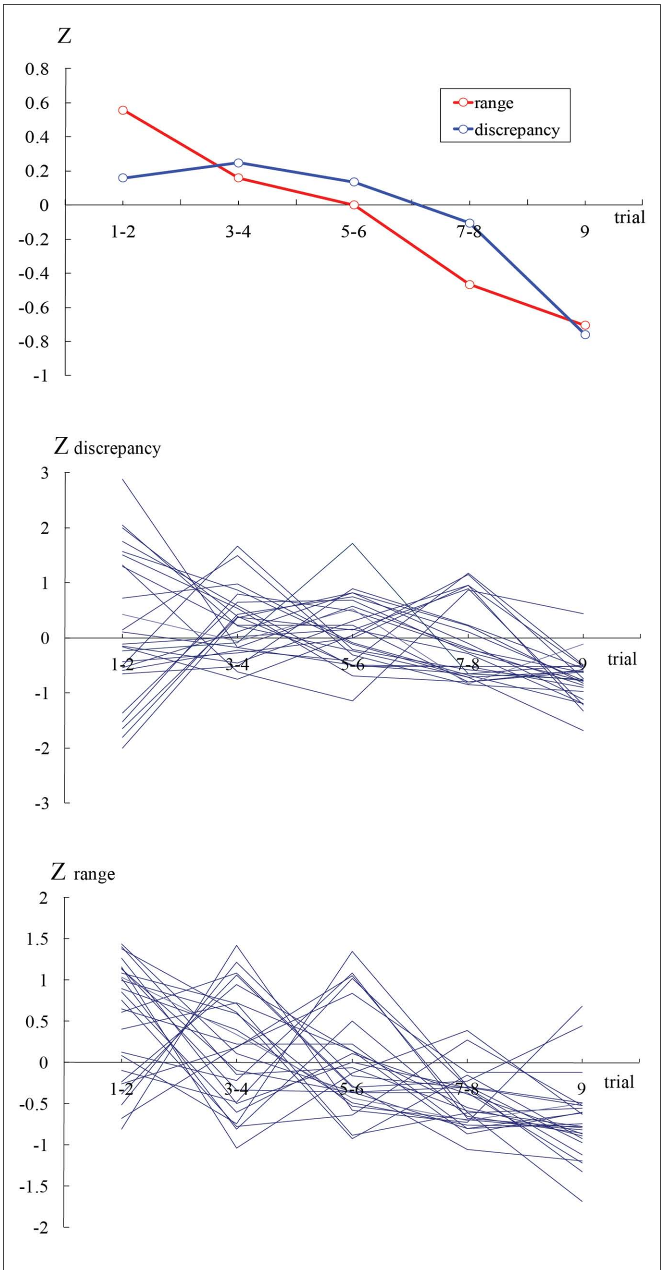

FIGURE 2 | The standardized discrepancy and range (adjusted for the number of foods) measures as a function of training trials. Top: means of the standardized discrepancy and range plotted against training trials. Middle: overlaid *z* scores for the range measures of individual participants plotted against training trials. Bottom: overlaid *z* scores for the discrepancy measures of individual participants plotted against training trials.

The means of table setting performance were also computed. The correlation of table setting performance with the discrepancy and range measures (see **Table 2**) showed that a higher number of tables set was associated with larger discrepancies and ranges. Table setting interfered with the cooking performance on range and discrepancy, indicating that participants followed the instructions to concurrently perform the cooking and table setting tasks.

TRAINING TRANSFER – WAIS SUB-TEST PERFORMANCE

The dependent measures used were WAIS scaled scores that reflect the relative standing of an individual in his or her respective age group. They may be more sensitive to the effect of training than the raw scores since age results in considerable individual differences for elderly participants. The difference between the post-test and the pre-test (baseline) performance was computed for the scaled scores of the arithmetic, letter–number sequencing, digit symbol coding and symbol search tests and the raw scores of the backward digit span (scaled scores were not available) and MMSE. There was significant increase in performance from pre-test to post-test or session effect for the arithmetic [$t(48) = 2.76$, $p < 0.01$, $\eta^2 = 0.14$], letter–number sequencing [$t(51) = 2.15$, $p < 0.05$, $\eta^2 = 0.08$], digit symbol coding [$t(51) = 2.48$, $p < 0.05$, $\eta^2 = 0.11$], and symbol search [$t(51) = 2.90$, $p < 0.01$, $\eta^2 = 0.14$] tests, but not backward span [$t(50) = 1.64$, $p > 0.10$] and MMSE [$t(47) = 0$, $p > 0.99$]. The difference scores were submitted to a one-way ANCOVA, treating group (control vs. training) as the between-subject variable and the baseline performance on each respective test as the covariate. There was no reliable effect of group for MMSE ($p = 0.76$), backward span ($p = 0.32$), and arithmetic ($p = 0.16$). Significant group effects were found for letter–number sequencing [$F(1,49) = 5.19$, $p < 0.05$, $\eta^2 = 0.07$] and digit symbol coding [$F(1,49) = 4.70$, $p < 0.05$, $\eta^2 = 0.09$]. **Table 3** listed the mean scores as the function of session and group. **Figure 3** showed the adjusted mean differences and SDs.

Table 2 | The correlations between table setting, discrepancy, and range performance.

	Mean tables set ***M* = 1.15** **SD = 0.87**	Mean discrepancy ***M* = 15.94** **SD = 9.25**	Mean range* ***M* = 6.18** **SD = 10.62**
Mean tables set	1.00	0.40 (*p* = 0.05)	0.39 (*p* = 0.05)
Mean discrepancy		1.00	0.25 (*p* = 0.22)
Mean range			1.00

**Range was adjusted by the number of foods cooked.*

Table 3 | Mean and SDs of test scores as the function of group (training vs. control) and session (pre-test vs. post-test).

	Training				Control			
	Pre-test		Post-test		Pre-test		Post-test	
	M	SD	*M*	SD	*M*	SD	*M*	SD
MMSE	28.58	1.36	28.73	1.59	28.09	2.04	27.65	2.46
Backward span	6.12	1.84	6.42	1.77	5.20	2.00	5.58	2.28
Arithmetic	10.20	3.28	11.08	3.07	9.50	2.43	9.77	2.69
Letter–number sequencing	10.27	3.42	11.92	3.01	9.50	3.41	9.85	3.18
Digit symbol coding	12.65	2.19	13.69	2.54	11.04	3.30	11.08	3.85
Symbol search	11.69	2.28	12.58	2.40	10.38	2.59	11.12	3.28

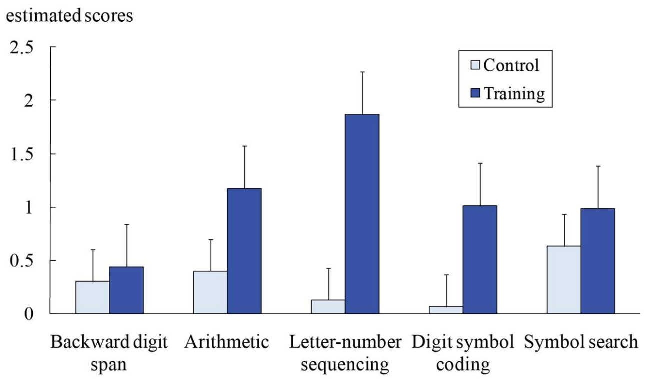

FIGURE 3 | The estimated difference between the pre-test and the post-test (i.e., post-test–pre-test, adjusted by pre-test performance) on backward digit span, arithmetic, letter–number sequencing, digit symbol coding, and symbol search tests as a function of training group.

The difference score was also submitted to a group (2) × tests(3) ANCOVA to examine if the training transfer effects exhibited on the backward span, arithmetic, and letter–number sequencing tests differ. The analysis showed that the difference between the post-test and the pre-test differed for the three tests [$F(2,95) = 19.40$, $p < 0.0001$, $\eta^2 = 0.16$] and a larger mean difference was observed for the training than the control participants [$F(1,50) = 6.06$, $p < 0.05$, $\eta^2 = 0.04$]. The interaction between group and tests failed to reach significance ($p = 0.19$), despite there was a trend toward such differences as shown in **Figure 3**. Planned comparison on the difference in the effect of group between the arithmetic test and the backward span was also not significant ($p = 0.27$).

The WAIS-III working memory index (WMI) and the processing speed index (PSI) were computed using the respective test scores: WMI = digit span + arithmetic + letter–number sequencing; PSI = digit symbol coding + symbol search. Significant session effect was observed on both the WMI [$t(48) = 3.78$, $p < 0.0005$, $\eta^2 = 0.23$] and the PSI [$t(51) = 3.53$, $p < 0.001$, $\eta^2 = 0.20$]. Submitting these two measures to ANCOVA, the effect of group was neither significant for WMI ($p = 0.14$) nor PSI ($p = 0.27$).

TRAINING GAIN AND WAIS PERFORMANCE

The relationships between test performance and training performance were examined to determine whether training improvements on the tests were associated with training gain. The slopes of the regression equation for discrepancy and range regressed over training sections were computed to serve as the measure of training gain. Seven participants were excluded from this analysis since their different ordering of task complexity (i.e., number of foods) may have affected the slopes. The correlations between slopes and pre-test/post-test differences on the WAIS scores were computed. The only significant correlation was that between the arithmetic difference score and training gain in discrepancy ($r = -0.50$, $p < 0.05$).

GENERAL DISCUSSION

The cooking training task significantly and specifically improved the elderly participants' performance on the outcome measures. Both training gains on the task and transfer effects on WAIS subtests were observed. Participants exhibited a better prospective memory (discrepancy) and planning performance (range) on the cooking task at the end than at the start of the training. Transfer effects were demonstrated on the letter–number sequencing and the digit symbol coding test, though little correlation was observed between training gains and the improvement on test measures.

The successful transfer observed on the letter–number sequencing test was likely the result of the control processes that it shared with the cooking training task (Buschkuehl et al., 2008). Letter–number sequencing has been used as a measure of manipulation span that involves executive control process of item manipulation and set switching between types of items (i.e., numbers and letters; Myerson et al., 2003; Emery et al., 2007). The cooking training task engaged the participant in repeated practice on the set switching between the cooking status information and task goal information as well as their updating. These practice increased the efficiency of the set switching and updating process that contributed to the greater improvements on letter–number sequencing test in the training than in the control participants. Significant transfer effects were not observed for the other two working memory measures – the backward span and arithmetic, supporting the prediction that the process overlap with the training task for these two measures was less than that of letter–number sequencing.

It is also worth noting that there was a modality difference between the training and transfer task. That is, the elderly participants were trained on a visual/spatial task while the transfer task of letter–number sequencing was auditory/verbal, suggesting that the transfer effect is supramodal in nature. This finding interestingly paralleled the supramodal transfers observed for working memory training that accompanied changes in brain activity in supramodal working memory-related regions (Olesen et al., 2004; Karzmark, 2009; Smith et al., 2009; Borella et al., 2010).

Training transfer was not observed on the processing speed measure of symbol search or the PSI, supporting the prediction that the current training task targets the executive control functions rather than processing speed. The significant transfer on digit symbol coding was, however, unexpected. In the digit symbol coding test, participants draw symbols below numbers according to a "look-up" table (that associates each number with a symbol) at the top of the page. It is noted that there are also two types of information (i.e., digits and symbols) in digit symbol coding as in the training task and the letter–number sequencing test. Participants switched between one type of information (digit) when engaging in one task component (coding) and the other type of information (symbol) when engaging in the other task component (copying). In the digit symbol coding, participants also shifted between the component task of coding and copying that share with the cooking training task the shifting process (between the cooking and table setting sub-tasks).

In fact, there is increasing evidence in support of the role of executive functioning in the digit symbol coding test (Holtzer et al., 2005; Baudouin et al., 2009; Hall et al., 2009), despite the general conviction that the test measures processing speed. Baudouin et al. (2009), for example, suggested that digit symbol coding performance reflected age-related differences in both executive functioning and perceptual speed. They found that partial correlations between digit symbol coding and executive function (partialing out perceptual speed) and between digit symbol coding and perceptual speed (partialing out executive function) were equivalent for the older adults but not for young adults. Treating the digit symbol coding as a measure tapping both executive function and processing speed is consistent with its effectiveness in explaining age-related decline in memory performance (Baudouin et al., 2009) and mortality rate (Rosano et al., 2008).

The potential relationships between the digit symbol coding test and executive function were also consistent with the proposal that the perceptual speed measures can be classified according to their processing demands (Ackerman and Cianciolo, 2000; Ackerman and Beier, 2007). Based on the factor analysis of common perceptual speed tests, the digit symbol coding test has been demonstrated to produce greater loading on the factor related to demands on working memory (i.e., PS-memory; Ackerman and Cianciolo, 2000; Ackerman and Beier, 2007) than others. This factor loading supports the exhibition of executive training transfer on digit symbol coding. The factor structure of the perceptual speed measures also help explain why transfer was observed on digit symbol coding but not on symbol search. In the symbol search test, participants judge whether two target symbols are present within a linear array of five symbols located to the right of the two targets. Although this test recruits the working memory (Sweet et al., 2005) as participants hold the symbols for comparison, it does not rely on working memory as much as the digit symbol coding test in which associations between digits and symbols are formulated and held for some while. The symbol search test should alternatively load high on the scanning factor (PS scanning) and its difference from the digit symbol coding test accounted for the differential transfer effects on these two tests (Ackerman, 1990).

Despite these findings, a "demand characteristics" interpretation of the training effects remains viable since the performance of the training participants was compared with that of a non-active control group. The increased contact of the training relative to the control group raised the possibility that demand characteristics may have played some role in the current findings. The specific, not general, transfer effects found in current study made demand characteristics a relatively unlikely account (Stine-Morrow and Basak, 2011). The transfer effect was observed only on letter–number sequencing and digit symbol coding. If this finding came from efforts of the training participants to meet experimenter expectations for better general performance after training, then significant transfer should have been observed on all other WAIS measures. If the training participants attempted to fulfill the demand that the training was targeting executive functioning, and the elderly participants of varying educational backgrounds were capable of analyzing the executive control components of the WAIS tests, then significant transfer effects should have been observed on all of the working memory-related tests and less likely on digit symbol coding performance. Demand characteristics thus cannot properly account for the training effects found in this study.

In the current study, the training transfer effects were verified using the analysis of covariance that raised the question of whether these effects were conditioned on one's baseline performance. That is, the cooking training may have benefited participants of specific ability profiles and not the others. Such an aptitude–treatment interaction has been demonstrated to affect the patterns of transfer effects in training studies (Goska and Ackerman, 1996). The benchmark cognitive training study ACTIVE (Willis et al., 2006) also observed a number of such interactions (McArdle and Prindle, 2008; Langbaum et al., 2009). Unverzagt et al. (2007), for example, found that elderly impaired on baseline memory performance (episodic memory) showed no benefit from the memory training provided by the ACTIVE program as much as elderly participants with normal baseline memory performance. Memory-impaired participants, however, benefited from the (processing) speed training as did memory-normal participants.

We have thus used the baseline performance on each respective measure as a rough ability measure for the individual to test for the presence of such an effect. The covariate (i.e., the baseline performance) × group interaction terms were additionally included in the ANCOVAs (for the examination of equal slopes). For all five transfer measures, the covariate by group interaction failed to reach significance (backward span, $p = 0.92$; arithmetic, $p = 0.13$; letter–number sequencing, $p = 0.91$; digit symbol coding, $p = 0.20$; symbol search, $p = 0.18$). Results of this analysis did not provide support for possible aptitude–treatment interaction in this study. The small sample size here could have prevented the analysis from gaining sufficient power though.

The current training effects were obtained over a relatively short training duration, i.e., five sessions and less than an hour in each. Although training transfers have been demonstrated for brief training (Buschkuehl et al., 2008; Borella et al., 2010), identification of factors underlying the success of transfer is relevant to the design of training program. First, the current cooking training task gradually increased its speed and varied its task complexity. Participants also needed to make adjustments on task prioritization according to their levels of capability as the speed and complexity of the task increased and varied across training trials. These features of the task are consistent with the proposal that effective training transfer is promoted by the maintenance of a relatively high task demand that challenges the information processing system (Buschkuehl et al., 2008; Hertzog et al., 2008; Jaeggi et al., 2008; Borella et al., 2010). The cooking task was also close to a variable-priority training (Kramer et al., 1995, 1999) with prioritization initiated by participants. The obtained short term transfer effect is thus also consistent with the role of prioritization in promoting training transfer (Stine-Morrow and Basak, 2011).

Second, in addition to these important basic features, the cooking task also took the form of a frequently encountered daily activity that increased the familiarity of task components. Older adults may be better able to compensate for cognitive deficits in executive functioning when the task contains elements that mimics their real-world experiences (Kliegel et al., 2007).

Third, the current cooking training task set up passing criterion and provided feedbacks of performance to participants in a manner that was directly related to the targeted behavior (i.e., discrepancy and range). Previous studies of executive function training in the elderly found limited (far) transfers to working memory measures (Burgess et al., 2005; Buschkuehl et al., 2008). Many of these studies did not enforce a passing criterion as the current one, nor did they provide feedbacks to participants of their learning performance (Burgess et al., 2005; Buschkuehl et al., 2008; Karbach and Kray, 2009; Thorell et al., 2009). An exception was the far transfer obtained from a video game training (Basak et al., 2008). The elderly participants were trained on a real-time strategy video game that provided them with individualized feedbacks and, likely, passing criterion (that determined when a particular game end). Basak et al. (2008) did find significant far transfer effects on executive control related measures (e.g., set switching, change detection) as the current study.

It is interesting to note that the cooking training task bears some similarity with the real-life meal preparation task in their task goal structure. Both the current computer task and the real-life task require the formulation of an overall plan, mental simulation of what may happen during the process, execution of specific actions according to the current goal and prioritization while maintaining other goals. Satisfactory completion of the real-life task may thus also recruit executive control process that oversees the arrangements of different task priorities to formulate a useful plan (Ward, 2005). Whether the daily practice with meal preparation enhances the efficiency of executive control processes (as in the current computer task) remains to be an interesting question. Despite the similarity in task goal structure, the real-life task differs from the computer task. On the one hand, automatic management of task information and goals could be easily developed from repeated practice when few or simple dishes are involved in real-life cooking. On the other hand, even when the real-life task involves cooking a large (complicated) meal, one's expertise at each of the component processes may vary (Ward, 2005) resulting in individual differences in the need for executive control during cooking. Overall, the recruitment of the executive control processes appears to be less frequent in the real-life cooking task than the current computer task.

The current findings are limited in several aspects. First, the lack of significant correlations between training gains on discrepancy/range and the transfer measures is unsatisfactory in terms of linking transfers to the aspects of training. A larger sample size would be needed to reveal such relationships. Second, it is not known whether the effects of training survive longer delays or whether they transfer to measures of daily performance (ADL or IADL, for example). Both the maintenance of training effects over time and the transfer to daily performance are critical indices for cognitive training because they serve as the basis for the "use it or lose it" hypothesis and the practice of cognitive training. Third, what is also unclear from current findings is how performance may vary if the training duration or intensity is increased. Such findings help determine what could be the most optimal or cost–effective training implementation. Fourth, the use of a no-contact control group had limited the interpretation of the training effects found due to potential confound in demand characteristics. Although the training effects found were specific rather than general that provisionally ruled out the confound, an improved design (i.e., that with an active control condition) may better clarify the nature of the training effects found in the current study.

To summarize, the current study showed training and transfer effects using a multitasking cooking training task. Learning was exhibited in the greater improvements on letter–number sequencing performance in trained vs. control participants. Features of the current training task may shed light on the design of effective training regimens for executive control in the elderly.

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