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Self-Regulatory Processes and Exercise Adherence in Older Adults

Executive Function and Self-Efficacy Effects

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Background: Self-efficacy and the use of self-regulatory strategies are consistently associated with physical activity behavior. Similarly, behavioral inhibition and cognitive resource allocation—indices of executive control function—have also been associated with this health behavior.

Purpose: The purpose of this study was to examine the hypothesis that self-efficacy mediates the relationship between self-regulatory processes, such as executive function, and sustained exercise behavior.

Methods: Older adults (N=177, mean age=66.44 years) completed measures of executive function, self-reported use of self-regulatory strategies, and self-efficacy prior to and during the first month of a 12-month exercise intervention. Percentage of exercise classes attended over the following 11 months was used to represent adherence. Data were collected from 2007 to 2010 and analyzed in 2010–2011. Structural equation models were tested examining the effect of executive function and strategy use on adherence via efficacy.

Results: As hypothesized, results showed significant direct effects of two elements of executive function and of strategy use on self-efficacy and of efficacy on adherence. In addition, there were significant indirect effects of strategy use and executive function on adherence via self-efficacy.

Conclusions: Higher levels of executive function and use of self-regulatory strategies at the start of an exercise program enhance beliefs in exercise capabilities, which in turn leads to greater adherence.

Trial registration number: This study is registered in Clinicaltrials.gov (NCT 00438347).
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Introduction

Maintaining a health regimen on a long-term basis is extremely difficult.^{1–3} Successful adherence often requires one to self-regulate one's behavior by overriding a well established response (e.g., watching TV) and replacing it with a less common but more desirable response (e.g., going for a brisk walk).⁴ There have been two approaches to examining self-regulatory processes relative to behavior change. The most common method in the social/health psychology literatures is to assess self-reported goal setting and intentions.

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The neurocognitive literature, however, takes a more biological perspective by assessing individuals' abilities to arrange, integrate, and control cognitive actions such as planning, decision making, error correction, troubleshooting, and resisting temptation.^{5,6} Collectively, these abilities are termed executive function.

Hall et al.⁷ examined the associations among self-reported intentions, physical activity, and executive function in a small sample of college students. Executive function accounted for variance in physical activity levels independent of self-reported intentions, and the interaction between intention and executive function contributed additional unique variance. Although physical activity was assessed over a very short period, thereby limiting our understanding of the role that executive function might play in long-term maintenance of physical activity, this study represents an important foundation for examining the role of executive function in lifestyle health behaviors.

Social cognitive theory (SCT)^{8,9} suggests that behavior change stems from changes in motivation and self-regulation.⁹ The core construct of SCT is self-efficacy: the belief one has in one's capabilities to successfully carry out a course of action.^{8,10} Self-efficacy is one of the most consistent determinants of many health behaviors,⁸ including physical activity.¹¹ Bandura⁸ has proposed that SCT integrates both cognitive and motivational elements of self-regulated behavior. Self-regulatory strategies such as planning, scheduling, and self-monitoring, operating within the SCT framework,¹⁰ may have both direct and indirect effects on health behavior. For example, Bates et al¹² reported that self-efficacy mediated executive function effects on substance abuse and Blume and Marlatt¹³ have suggested that studying the relationship between executive function and self-efficacy may be necessary for effectively modifying interventions and behavior change practices. Given that adherence to structured exercise programs is consistently associated with higher exercise-related self-efficacy,¹¹ the effects of executive function on adherence should work, at least in part, through self-efficacy.

In this article, secondary outcomes data are presented from a 12-month exercise trial designed to examine exercise effects on brain structure and function in older adults. Importantly, older adults have more compromised executive function than their younger counterparts^{14–16} and they exhibit low levels of physical activity.¹⁷ The purpose of the present study was to examine the potential for executive function processes to predict adherence to physical activity. It was hypothesized that executive function performance and self-reported use of self-regulation strategies would influence older adults' adherence to a 12-month exercise intervention through the mediation of exercise-specific self-efficacy.

Methods

Participants and Procedure

Participants (N=177, men=61, women=116; mean age=66.44±5.69 years) were community-dwelling older adults who volunteered to participate in a 12-month organized exercise intervention. Recruitment procedures, full inclusion–exclusion criteria, and study details have been described elsewhere.^{14–16} Briefly, participants were recruited via local media outlets. Inclusion criteria pertinent to the present data included being inactive (i.e., defined as a lack of regular involvement in exercise during the previous 6 months); having no medical conditions likely to be exacerbated by physical activity; right handed; and passing a Modified Mini Mental Status Exam.¹⁸ Participants who passed prescreening criteria were required to obtain physician consent for participation in the exercise program. Data were collected from 2007 to 2010 and analyzed in 2010–2011.

Once accepted into the study, participants completed measures of demographics and self-regulatory strategies for being active. On

a separate occasion, participants also completed a computerized neuropsychological battery assessing several measures of executive function. All testing took approximately 2 weeks to complete. After baseline data collection, participants were randomized into one of two conditions: a walking group or a flexibility, toning, and balance (FTB) group. Classes met 3 days per week for approximately 1 hour over the 12-month period.^{14,19} All participants completed the self-efficacy measures after the third week of the program based on previous recommendations, as efficacy is likely to be overestimated at baseline.^{19,20}

Measures

Demographics. A brief questionnaire assessed basic demographic information including participants' age, gender, and education.

Executive functioning. Following the recommendations of Miyake et al.,²¹ multiple measures of executive function were used to determine individual contributions of different executive function processes. These are described below.

Dual task. In this measure of task coordination,^{22,23} two conditions are presented in which participants respond to one (single task) or two (dual task) stimuli. The single-task trials involve the presentation of either a single letter (A or B) or number (2 or 3) stimulus whereas in the dual-task trials, two stimuli, a letter and a number, are presented. Participants respond to the stimuli using a hand-held button press. Each participant completed 48 trials and had to respond as quickly and as accurately as possible to the stimulus. The percentage of incorrect responses was the outcome measure for this task.

Stroop color-word task. The modified Stroop task²⁴ consisted of four trial types: congruent, neutral, incongruent–eligible, and incongruent–ineligible. The congruent condition consisted of words presented on a screen that were printed in an ink color that matched the color of the stimuli (e.g., BLUE in blue color), whereas the neutral condition consisted of words that were matched for the length and frequency of the color of the stimuli but not color category (e.g., SHIP in blue color). The incongruent–eligible stimuli involved the presentation of words that matched one of the potential responses (e.g., BLUE in red ink if “blue” was one of the potential responses). Incongruent–ineligible stimuli presented words that did not match the set of potential responses (e.g., PURPLE in blue ink if “purple” is not one of the potential responses). Two ink-color sets were used and counterbalanced across participants who were instructed to respond as quickly and as accurately as possible. The outcome measure was calculated as the mean time for the eligible trials plus ineligible trials minus time for congruent trials divided by congruent trials time. This provided a measure of cost interference whereby higher scores represented less interference.

Flanker task. A modified flanker paradigm^{14,25} required participants to identify the orientation of a central arrow cue that was flanked by arrows that were in either a congruent (e.g., >>>>>) or incongruent (e.g., >><<>>) orientation. The outcome of interest was proportional cost or inhibition and was calculated by subtracting the reaction times of congruent trials from those of incongruent trials and dividing by the reaction time of congruent

trials. Such an approach accounts for individual differences in perceptual speed.

Wisconsin Card-Sorting Test. Working memory, inhibition, and task-switching processes were assessed using a computerized version of the Wisconsin Card-Sorting Test (WCST)²⁶ previously described by Voss et al.¹⁴ The outcome measure for this task was percentage of perseverative error (i.e., total number of repeated error trials divided by number of trials multiplied by 100).

Task-switching. This task has previously been described by Voss et al.¹⁴ Participants were asked to switch between judging whether a number (1, 2, 3, 4, 6, 7, 8, or 9) was odd or even and judging whether it was low or high (i.e., smaller or larger than 5). The outcome measure for this task was a measure of cost calculated by the difference in performance for trials when the preceding trial involved the same task (nonswitch/repeat trial) and those when the preceding trial was of the alternative task (switch trial).

Use of self-regulatory strategies. Use of physical activity self-regulatory strategies was assessed by the 12-item Physical Activity Self-Regulation scale (PASR-12).^{27,28} The PASR-12 is composed of six strategy subscales including self-monitoring, goal setting, eliciting social support, reinforcement, time management, and relapse prevention. Items are rated from 1 (never use strategy) to 5 (use strategy very often). Each of the subscales was used as a manifest indicator of the latent construct representing physical activity self-regulation. Internal consistency for subscales ranged from $\alpha=0.79$ – 0.94 .

Self-efficacy. Perceptions of one's confidence to adhere to an exercise regimen over time, exercise in the face of potential barriers, and to accumulate physical activity were assessed with the Exercise Self-Efficacy scale (EXSE),²⁹ the Barriers Efficacy scale (BARSE),³⁰ and the Lifestyle Efficacy Scale (LSE),³¹ respectively. These measures were assessed at the end of the third week of the exercise intervention to ensure accurate assessments of efficacy judgments.^{20,22} Possible scores for each measure ranged from 0 to 100, as per measurement convention for self-efficacy assessment, and all measures had excellent internal consistencies ($\alpha \geq 0.93$).

Exercise adherence. Given that self-efficacy was assessed at 3 weeks into the program, adherence reflects the percentage of attendance to exercise classes over the last 11 months of the program. Attendance data were recorded each day by staff, aggregated, and divided by the total possible number of sessions to arrive at percentage attendance.

Data Analytic Strategy

Data were analyzed using Mplus, version 6.0, with a robust maximum likelihood estimator. Goodness-of-fit tests included the chi-square statistic, root mean square error of approximation (RMSEA), comparative fit index (CFI), and standardized root mean square residual (SRMR). Chi-square *p*-values at or higher than 0.05, RMSEA at or below 0.06, CFI higher than 0.95, and SRMR lower than 0.08 are indicative of good model–data fit.^{32,33} A measurement model was initially tested, followed by the hypothesized structural model. The measurement model involved a two-factor latent variable model including self-reported use of physical activity self-regulatory strategies (i.e., six subscales of the PASR-12) and exercise self-efficacy (i.e., the three efficacy measures).

Executive function measures were treated as manifest variables.²¹ Next, the observed 11-month attendance rate were added as a distal outcome to the model, and tested direct effects of executive function measures and self-regulation strategy use on self-efficacy, and self-efficacy on adherence, and indirect effects of executive function and self-regulation strategy use on adherence via self-efficacy. Age, gender, and education were included as covariates. Given the directional hypothesis of the current model, a one-tailed *p*-value of 0.05 was adopted. To ease interpretation of model paths in Figure 1, only standardized estimates were reported and demographic paths were omitted.

Results

Preliminary Analysis

Characteristics of the sample have been described elsewhere.¹⁹ Briefly, participants in the current study ranged in age from 58 to 81 years ($M=66.44$, $SD=5.69$) and 65.5% were women. The majority of the sample was white (91%) and had also completed at least 1 year of college or more (79.6%). Percentage attendance was 69.85% ($SD=26.42$) in the walking condition and 68.55% ($SD=26.74$) in the FTB condition for the 11-month period; these levels were not statistically different from each other, $t(175)=0.326$ $p=0.74$. Subsequent analyses used attendance for the total sample. Table 1 details descriptive statistics and Table 2 shows correlations among all variables.

Structural Equation Modeling

The initial two-factor (i.e., PASR-12 and self-efficacy) latent variable measurement model provided an adequate fit to the data ($\chi=34.61$ [25], $p=0.10$, $CFI=0.99$, $RMSEA=0.05$ [90% CI=0.00 to .08], $SRMR=0.06$) and all specified loadings were significant. Next, a model specifying *direct effects* of the executive function measures and physical activity self-regulation use on self-efficacy was tested; direct effects of the executive function measures, physical activity self-regulation, and self-efficacy on 11-month attendance; and the *indirect effects* of the executive function measures and physical activity self-regulation on attendance via self-efficacy. Age, gender, and education were included as covariates in the model, which provided a good fit to the data ($\chi=141.40$ [103], $p=0.01$, $CFI=0.96$, $RMSEA=0.05$ [90% CI=0.03 to 0.06], $SRMR=0.06$).

As hypothesized, there was a significant path from self-regulatory practices to self-efficacy ($\gamma=0.21$, $z=4.33$, $p=0.015$) and from the dual task ($\gamma=-0.25$, $z=-4.54$, $p=0.01$) and Stroop measures ($\gamma=0.18$, $z=4.04$, $p=0.02$) to self-efficacy. Additionally, as hypothesized, only self-efficacy was directly associated with attendance ($\gamma=0.34$, $z=6.31$, $p<0.01$). In addition, the *indirect* effect from self-regulatory practices to attendance through self-efficacy was significant ($\beta=0.07$, $z=3.70$, $p=0.03$), as

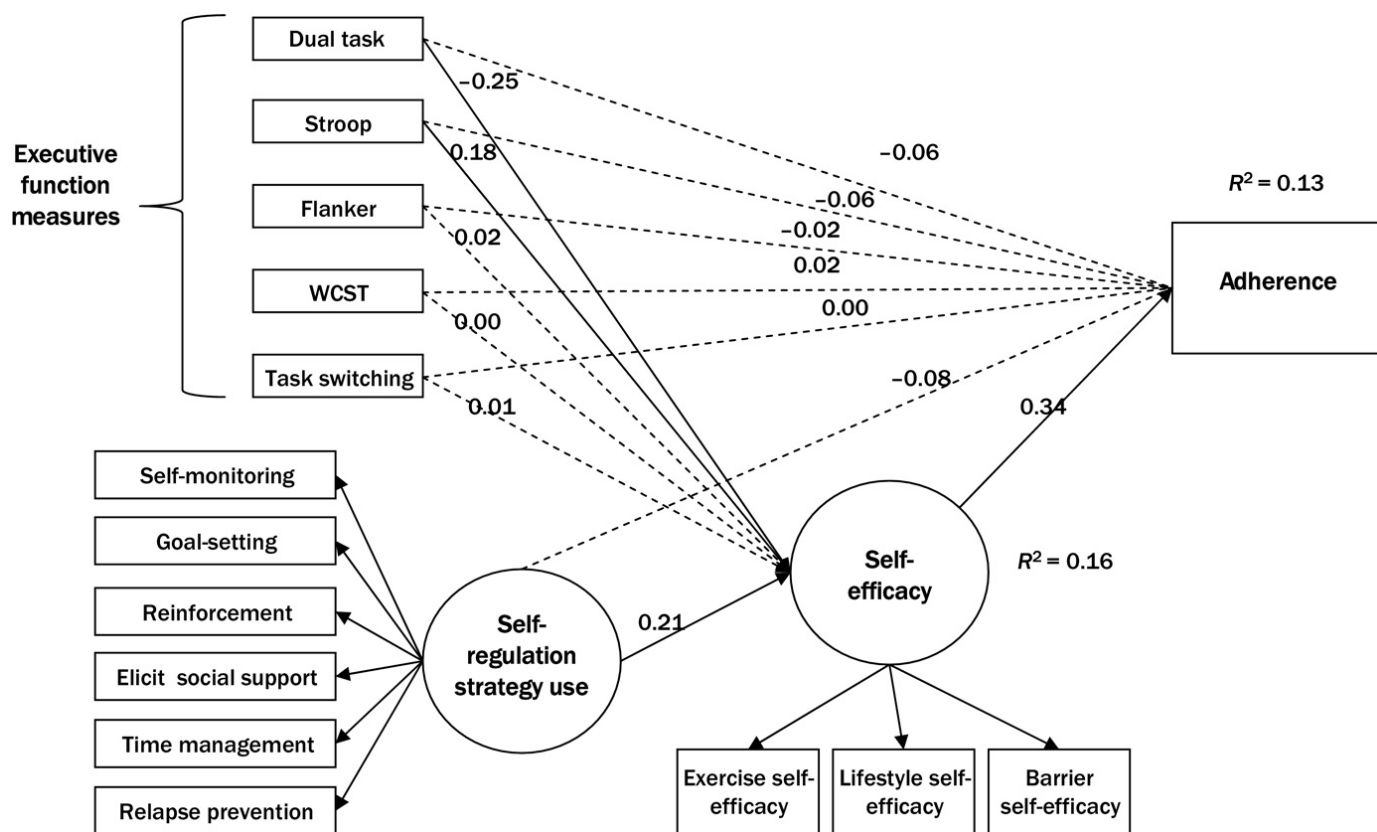


Figure 1. Structural equation model of relationships among executive functioning, self-efficacy, and adherence
 Note: Solid lines represent significant paths ($p < 0.05$, one-tailed); dotted lines represent nonsignificant paths. For clarity, covariate effects have been omitted.
 WCST, Wisconsin Card-Sorting Test

were the indirect effects of the dual task error and Stroop to attendance through self-efficacy ($\beta = -0.08$, $z = -3.44$, $p = 0.04$ and $\beta = 0.06$, $z = 3.34$, $p = 0.05$, respectively).

There were several significant associations among the current covariates and other model constructs. Interestingly, participants with lower levels of education had higher levels of self-efficacy ($\beta = -0.19$, $p < 0.05$). As one might expect, older adults produced more errors on the dual task ($\beta = 0.22$, $p < 0.01$) and those with less education produced more errors on the dual task ($\beta = -0.13$, $p < 0.05$) and Wisconsin Card-Sorting Task ($\beta = -0.18$, $p < 0.01$). Finally, men reported greater use of physical activity self-regulation strategies than did women ($\beta = 0.14$, $p < 0.05$). This model accounted for 13% of the variance in attendance.

Discussion

The results suggest that higher levels of *some types* of executive function (i.e., task coordination and inhibition of habitual response) and greater use of self-regulatory strategies were associated with higher levels of exercise self-efficacy at 3 weeks into the trial. In turn, higher efficacy was associated with better adherence to weekly exercise classes for the subsequent 11 months. Thus, in-

dividuals who regularly engage in strategies such as self-monitoring, eliciting social support, and managing time are likely to have stronger perceptions of their capabilities to regularly engage in physical activity over time, which leads to better program adherence. Similarly, individuals who are better able to multitask and inhibit habitual responses (e.g., engaging in sedentary behaviors) are also more efficacious and, consequently, more likely to adhere to exercise regimens.

These findings underscore the importance of integrating both cognitive and motivational elements of self-regulated behavior as sources of efficacy information. The results also support and extend the work of Hall et al.⁷ by showing that executive function is implicated in the maintenance of long-term health behavior but that the relationship is indirect. Importantly, these findings were demonstrated in a relatively large exercise trial across an 11-month period. Moreover, older adults were the focus of this study, a segment of the population known to have compromised executive function^{34,35} and poor physical activity behaviors.¹⁷

Adoption and maintenance of healthy lifestyle behaviors requires individuals to effectively solve problems, engage in goal-directed behavior and behavioral

self-control, and inhibit habitual, often unhealthy, behaviors. Numerous measures can be used to assess executive function, although typically studies rely on relatively few.³⁶ Miyake et al.²¹ have suggested that potentially important relationships could be missed in this way and that multiple measures should be administered.

In the present study, five measures of executive function were used, and performance on the modified Stroop and dual-task measures were directly associated with self-efficacy and indirectly associated with adherence. If only the Flanker task, the WCST, or the task-switching paradigm were used, it would have been concluded that executive function and efficacy were unrelated. This further suggests that inhibitory control and multitasking are more important for adherence than is cognitive flexibility. Whether this is

unique to exercise as a health behavior or has implications for other health regimens remains to be determined.

It is suggested that understanding how executive function and behavior change are related is as impor-

Table 1. Sample demographics and means

	M or %	SD	Range
Age (years)	66.44	5.69	58–81
Gender (% women)	65.5%	—	—
Education (≥1 year of college)	79.60%	—	9th grade–PhD or equivalent
Executive function measures			
Dual task % error	16.58%	17.92%	0.00% to 90.00%
Stroop task interference	9.25	11.94	–42.90 to 40.34
Flanker proportional cost	14.03	10.03	–32.07 to 50.71
WCST % perseverative error	17.42%	10.46%	4.00% to 71.00%
Task-switching cost	358.71	202.63	–673.50 to 866.00
PASR-12 total score	27.39	11.00	12.00 to 59.00
Self-efficacy			
Exercise self-efficacy	76.17	21.00	6.67 to 100.00
Barriers self-efficacy	67.32	20.82	16.15 to 100.00
Lifestyle self-efficacy	71.73	24.35	0.00 to 100.00
Attendance	69.19%	26.52%	0.00% to 100.00%

Note: Attendance is the attendance for the last 11 months of the program. Education is the percentage of individuals who completed 1–3 years of college or more. PASR-12, physical activity self-regulation questionnaire, 12-item version; WCST, Wisconsin Card-Sorting Test

Table 2. Correlations among study constructs

	1	2	3	4	5	6	7	8	9	10
1. Dual-task % error	—	.04	0.02	0.28**	0.22**	0.08	–0.23**	–0.16*	–0.05	–0.10
2. Stroop task cost	—	—	0.08	0.03	–0.14	–0.05	0.06	0.04	0.16*	–0.01
3. Flanker proportional cost	—	—	—	–0.04	–0.06	0.07	–0.03	0.04	0.09	–0.04
4. WCST % per errors	—	—	—	—	0.02	–0.02	–0.04	–0.03	0.03	0.01
5. Task-switching cost	—	—	—	—	—	0.03	–0.11	–0.05	0.04	–0.02
6. PASR-12 total score	—	—	—	—	—	—	0.10	0.05	0.23**	–0.03
7. Exercise self-efficacy	—	—	—	—	—	—	—	0.46**	0.60**	0.20**
8. Barriers self-efficacy	—	—	—	—	—	—	—	—	0.46**	0.24**
9. Lifestyle self-efficacy	—	—	—	—	—	—	—	—	—	0.16*
10. Attendance	—	—	—	—	—	—	—	—	—	—

Note: Attendance is the attendance for the last 11 months of the program. PASR-12, physical activity self-regulation questionnaire, 12-item version; per errors, perseverative errors; WCST, Wisconsin Card-Sorting Test * $p < 0.05$; ** $p < 0.01$ (two-tailed)

tant as determining which behaviors influence executive function. For example, lower levels of executive function were associated with lower self-efficacy among individuals seeking treatment for alcohol abuse¹³ and greater cognitive deficits, including executive function, have been associated with lower levels of self-efficacy and poorer adherence to therapy.¹² Blume and Marlatt¹³ further suggest that we need to know more about how executive function influences predictors of behavior change such as self-efficacy and outcome expectations. The current findings contribute further to understanding the executive function–self-efficacy behavior change relationship.

How should one apply such findings to further influence physical activity behavior change in older adults? One approach might be to teach participants self-control strategies and offer an array of coping strategies from which to choose, as a solution to inhibiting habitual poor health behaviors (e.g., substituting stairs for elevators, parking further away from one's workplace). Additionally, it would be of interest to determine whether dual task training^{22,37} has the effect of not only improving cognitive performance but also influencing self-efficacy. An interesting approach would be to examine both the independent and synergistic influences of cognitive function training programs that target executive function and SCT-based exercise interventions on the relationships reported herein.

This study contributes to the literature and represents the first study to examine the relationships between executive function and adherence to an exercise intervention for older adults. Further, this study extends the work of Hall et al.⁷ by using a substantially larger sample of participants and placing the hypothesis relative to the self-regulation behavior relationship within an SCT framework. In so doing, it has been demonstrated that executive function does have important ramifications for adherence through the mediation of self-efficacy. That the effect was demonstrated across an 11-month period is also an important contribution.

Several limitations may be noted that might temper interpretation of the data. First, the sample was composed primarily of white, female, and relatively well-educated older adults, and thus generalization to other more-diverse populations is difficult. It should also be recognized that the pattern of relationships described is unidirectional and that exercise history and efficacy beliefs based on previous experience may influence executive function. Finally, the model tested is relatively simple and it is clear that other important physical, psychological, and environmental factors come into play in the prediction of this complex health behavior.

Conclusion

These findings suggest that elements of self-regulatory capacity, such as executive function and strategy use, influence adherence to exercise behavior in older adults through the mediation of self-efficacy. Such findings highlight the importance of executive function and self-efficacy in one's ability to self-regulate challenging health behaviors. Finally, they may also suggest that baseline assessment of executive function prior to the beginning of exercise programs may identify individuals whose self-regulatory capacity is indicative of potential poor adherence. Armed with this knowledge, interventionists could effectively put into operation strategies to prevent attrition.

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