Dual-task mobility among individuals with chronic stroke: Changes in cognitive-motor interference patterns and relationship to difficulty level of mobility and cognitive tasks

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Abstract

BACKGROUND: Dual-task mobility performance is compromised after stroke.

AIM: This study evaluated how the difficulty level of mobility and cognitive tasks influenced the cognitive-motor interference pattern among individuals with chronic stroke and whether it differed from age-matched control participants.

DESIGN: A cross-sectional study.

SETTING: University laboratory.

POPULATION: Individuals with chronic stroke and age-matched controls.

METHODS: Sixty-one individuals with chronic stroke (mean age: 62.9±7.8 years) and 32 controls (mean age: 61.0±7.3 years) performed three mobility tasks (forward walking, obstacle-crossing, backward walking) and two cognitive tasks (serial-3-subtractions, serial-7-subtractions) in single-task and dual-task conditions. time to complete the mobility tasks and correct response rates were recorded.

RESULTS: Serial subtractions significantly increased the walking time compared to single-task walking ($p<0.001$) without decreasing the correct response rate ($p>0.05$) in both groups, indicating cognitive-related motor interference. As the difficulty of the walking task was increased (i.e., obstacle crossing), the dual-task effect on the walking time was similar to that observed during forward walking, but the correct response rate significantly decreased ($p<0.05$), indicating that more attentional resources were allocated to the mobility task. When the walking task difficulty level increased further (i.e., backward walking), an exaggerated increase in the walking time ($p<0.001$) was observed in both groups, but the stroke group also had a decreased correct response rate ($p<0.001$), indicative of a mutual interference pattern. The control group, however, maintained the correct response rate ($p>0.05$) despite the slowed walking speed in this condition ($p<0.001$).

CONCLUSIONS: The degree of dual-task interference and task prioritization strategies are highly specific to the combinations of the walking and cognitive tasks used and are affected by the presence of stroke.

CLINICAL REHABILITATION IMPACT: The study results may provide the basis for establishing assessment tools and creating intervention programs that address dual-task mobility function post-stroke.

Word Count: 295

Keywords: gait, cognition, cerebrovascular accident, cognitive neuroscience

Introduction

Ambulation is an important functional activity that provides a sense of independence and inclusion in the community,[1] and it is one of the top priorities identified in rehabilitation goal setting by individuals after stroke.[2] Functional ambulation requires the ability to maintain walking performance while engaging in other tasks that demand attentional resources, such as walking while holding a conversation or walking in a busy shopping mall. The ability to perform a cognitive task while walking (i.e., dual-tasking) has gained increasing attention in stroke rehabilitation.[3]

When a mobility task is performed simultaneously with a cognitive task, there may be deterioration in the performance of one or both tasks compared with the performance of each task alone. This phenomenon is called cognitive-motor interference.[3] According to the limited capacity model, one's attention has a finite capacity.[3-4] In dual-task scenarios, both mobility and cognitive tasks may compete for the same attentional resources, and the uncompromised performance of dual tasks only occurs if the limit in attentional resources is not exceeded.[5-7] The extent of interference varies in different dual-task conditions because of the different mechanisms involved in executing various attention-demanding tasks.[8]

Mounting evidence has shown that cognitive-motor interference is compromised in individuals post-stroke,[1,9] but few studies have compared the interaction effects between different mobility and cognitive tasks. Plummer-D'Amato et al. assessed how adding a walking task would affect performance during three cognitive tasks (i.e., visuospatial, working memory, and spontaneous speech) in individuals post-stroke, and found that interference effects were apparent in spontaneous speech only.[10] More recently, Patel & Bhatt et al. evaluated the effects of adding different types of cognitive tasks (i.e., serial subtraction, Stroop test, and visuomotor reaction time task) during walking.[1] The highest motor cost was found for the serial subtraction task, whereas the highest cognitive cost was found for the visuomotor reaction time task. In both studies, the sample size was small (13 and 10 respectively). A control group was also lacking. It is thus uncertain whether the findings are specific to stroke. Only one walking task was evaluated, with no variation in its difficulty level. The cognitive tasks used were of different domains of cognitive function and may involve different neural substrates.[11-21] However, it is not certain whether the difference in the difficulty level of the cognitive task or the difference in the cognitive domain explains the difference in the degree and pattern of cognitive-motor interference across the different cognitive test conditions.[22] The influence of varying the difficulty level of tasks that belong to the same domain of cognitive function has not been assessed previously. It would also be interesting to assess how mobility and cognitive tasks interact to determine the degree and pattern of cognitive-motor interference.

The objective of this study was to evaluate how the difficulty level of mobility and mental tracking tasks influences the cognitive-motor interference patterns during dual-task conditions among individuals with chronic stroke and how these patterns were different from individuals without a stroke history. We hypothesized that the difficulty levels of the mobility and mental tracking tasks would interact with each other in determining the dual-task interference on mobility and mental tracking performance and that the dual-task interference patterns in individuals with stroke would differ from their counterparts without a stroke history.

Methods

Participants

Participants were recruited from community stroke self-help groups via convenience sampling. Inclusion criteria were as follows: 1) a diagnosis of hemispheric stroke in the chronic stage (onset ≥6 months), 2) age ≥50 years, 3) community-dwelling individuals, 4) able to follow two-stage commands, 5) able to ambulate without manual assistance for at least 15 meters (with or without walking aids). Exclusion criteria were as follows: 1) those with receptive or expressive aphasia, 2) other diseases or conditions influencing walking and balance, and 3) those with pain during standing or walking. Healthy older adults were also recruited to establish the control group. The same eligibility criteria were applied other than a history of stroke.

This study was approved by the Human Ethics Research Subcommittee of the involved university (approval number: HSEARS20130209002-01). Informed consent was obtained from all participants before data collection. All experiments were conducted in accordance with the Declaration of Helsinki.

Demographics

The medical history and other relevant information were obtained by interviewing the participants. The Geriatric Depression Scale-Short Form was used to evaluate the severity of depressive symptoms.[23] The Montreal Cognitive Assessment (MoCA) was used to assess cognitive function.[24] The Chedoke-McMaster Stroke Assessment was used to evaluate the degree of motor impairment of the affected lower extremity.[25] The disability level was assessed by the Modified Rankin Scale.[26]

Mobility tasks

Three walking tasks with an increasing level of difficulty were used. A 14-meter walkway was used for all 3 walking tasks. The time taken (in seconds) to complete the middle 10 meters of the walkway was recorded using a stopwatch, and this time was used as an indicator of how well the participants performed the following walking tasks.

(1) Forward walking: Participants walked along a 14-meter walkway in a forward direction.[27]

(2) Obstacle crossing: The testing protocol was adapted from the studies by Takatori et al. and Said et al.[28,29] Participants crossed a series of obstacles when walking forward. Seven obstacles (length 80 cm, width 5 cm, height 4 cm) were placed along the middle 10 meters of the walkway, with a distance of 1.5 meters between each obstacle (Figure 1).

(3) Backward walking: Participants walked in a backward direction along the same 14-meter walkway without obstacles.

Cognitive tasks

The serial-3 subtraction task and serial-7 subtraction task, representing two levels of difficulty in the mental tracking domain of cognitive function,[30] were used in our testing paradigm.[31,32] Participants were asked to repeatedly subtract 3 or 7 from a random number between 90 and 100. The number of correct answers was counted.

The correct response rate (CRR) was used as an indicator of how well participants performed the serial subtraction tasks. The CRR was calculated as follows.[31-34]

$$\text{CRR} = (\text{number of correct responses} \div \text{walking time}) \times 100\%$$

This study included six dual-task conditions (a mobility task with three levels of difficulty × a cognitive task with two levels of difficulty). Yang et al. used the same walking and cognitive tasks and found that the dual-task walking time and CRR measurements had good reliability.[35]

Assessment of single-task and dual-task performances

Each participant performed the aforementioned walking tasks in a single-task condition (i.e., without a cognitive task), followed by a dual-task condition (i.e., simultaneous performance of a mobility task and cognitive task). The sequence of the walking and cognitive tasks was randomized by drawing ballots. The order of the walking tasks was randomized first, followed by the order of the cognitive tasks. For each dual-task assessment, the following instruction was given: “Please perform both tasks as best as possible.” Before data collection, the testing procedures were thoroughly explained and a practice trial was provided to familiarize participants with the tasks and assessment procedures. A 2-minute rest period was provided after each testing condition to minimize physical and mental fatigue. A longer period was given upon request by the participants. Four of the participants used a cane during testing for all mobility tasks in both single- and dual-task conditions (Table 1).

To avoid mental rehearsal for the dual-task assessments, the specific starting number for the serial-3 or serial-7 subtraction task was not revealed to the participants until they approached the beginning of the 10-meter walking distance. The starting number used in the practice trial was not used in the actual trial.

After the aforementioned assessments were completed, participants were asked to perform the same cognitive task in a sitting position (i.e., a single-task condition). The time given to perform a specific cognitive task during a single-task condition was matched to that in the corresponding dual-task condition. For example, if it took the participant 25 seconds to complete the backward walking task while performing serial-3 subtractions, 25 seconds would also be given for serial-3 subtractions under single-task condition. As there were three dual-task combinations for each of the serial-3 and serial-7 subtraction tasks, each with a different walking time, three different CRR values were generated for each of the cognitive tasks under the single-task condition. The entire experimental session lasted approximately 1.5 hours.

Sample size calculation

Hyndman et al.[9] compared the walking performance under single-task and dual-task conditions (in conjunction with remembering a shopping list) between stroke patients (n=35) and age-matched controls (n=24). A significant interaction between task condition and group was found, with medium effect size (f=0.275). A similar effect size was assumed for this study. Based on an α value of 0.05, a power of 0.8, f=0.275, and 3 walking tasks, a sample of 20 participants (10 per group) would be required to detect walking task × group interaction effect. As there were 3 different cognitive test conditions (single-task, serial-3-subtractions, and serial-7-subtractions), we aimed to recruit a minimum of 30 (i.e., 10 × 3) individuals with stroke and 30 healthy controls.

Statistical analysis

All statistical analyses were conducted using SPSS software (version 20.0, IBM Corp., Armonk, NY, USA). The level of significance was set at $p \leq 0.05$. First, for each of the stroke and control groups, a two-way ANOVA with repeated measures [within-subject factors: cognitive task (three levels: no cognitive task vs. serial-3 subtractions vs. serial-7 subtractions) and mobility task (three levels: forward walking vs. obstacle crossing vs. backward walking)] was done to assess the difficulty level of the cognitive task and that of the mobility task and their interactions with walking time. Another two-way ANOVA with repeated measures was used to determine the influence of these same factors on the CRR [within-subject factors: cognitive task (four levels: single-task serial-3 subtractions vs. single-task serial-7 subtractions vs. dual-task serial-3 subtractions vs. dual-task serial-7 subtractions) and mobility task (three levels: forward walking vs. obstacle crossing vs. backward walking)]. This was followed by post-hoc contrast analysis with Bonferroni adjustment. The effect size of the ANOVA was represented by partial eta squared (η_p^2; $\eta_p^2 \leq 0.01$: small; $0.06 > \eta_p^2 > 0.10$: medium; $\eta_p^2 \geq 0.14$: large).[36]

Results

Participants' characteristics

Sixty-seven individuals with stroke and 35 healthy older adults were screened. Three individuals with stroke could not perform the serial subtraction task while sitting, and another three had aphasia, while three healthy older adults declined to participate. Therefore, complete datasets collected from 61 individuals with stroke (mean±SD age: 62.9±7.8 years) and 32 healthy older adults (mean±SD age: 61.0±7.3 years) were analyzed. The key characteristics of the participants are shown in Table 1. The level of motor impairment in the affected leg was mild to moderate among the participants with stroke, as indicated by the Chedoke-McMaster Stroke Assessment score [median (interquartile range)] for the leg [6 (4, 6)], foot [4 (3, 5)]. The median (interquartile range) Modified Rankin Scale score was 2 (1, 2), indicating no to slight disability. There was a small but significant difference in MoCA score between the stroke group and control group (mean difference=1.3, 95% CI=0.2, 2.3, p=0.019). However, there was no significant difference in the attention sub-scale between the two groups (p=0.504). No significant difference was found in other key characteristics between the two groups.

Walking performance in single-task condition

Results obtained from the single-task trials (Supplementary Table 1) showed that the mean walking time values for the 3 mobility tasks were all significantly different from each other in both groups ($p \leq 0.001$), confirming that backward walking was the most difficult, followed by obstacle-crossing and forward walking. The mean walking time for each of the mobility tasks was significantly longer in the stroke group than in the control group ($p<0.001$).

During the single-task condition, the CRR values (Supplementary Table 1) in both the stroke and control groups were significantly greater for the serial 3-subtraction task than for the serial-7 subtraction task ($p<0.01$). This was true regardless of the time given to perform the task, which was matched to the corresponding walking time during the dual-task conditions. This confirmed that the serial-7 subtraction task was more difficult than the serial-3 subtraction task. Overall, there was no significant difference in the CRR values of the serial-3 ($p>0.30$) or serial-7 subtraction task ($p>0.10$) in single-task conditions between the stroke and control groups.

Dual-task effect on walking time

In both groups, the main effects of the cognitive task (stroke group: F=41.584, $p<0.001$, $\eta_p^2=0.409$; control group: F=22.008, $p<0.001$, $\eta_p^2=0.415$), the mobility task (stroke group: F=74.004, $p<0.001$, $\eta_p^2=0.552$; control group: F=36.112, $p<0.001$, $\eta_p^2=0.538$), and the cognitive task × mobility task interaction effect on walking time were all significant (stroke group: F=15.506, $p<0.001$, $\eta_p^2=0.205$; control group: F=4.481, p=0.023, $\eta_p^2=0.126$) (Figure 2A and 2B).

Post-hoc analysis showed that in each of the stroke and control groups, the mean walking time values were significantly longer in the dual-task conditions than in the corresponding single-task conditions, regardless of the walking task performed ($p<0.01$) (Supplementary Table 1). As the difficulty level of the cognitive task was increased (serial-3 subtractions vs. serial-7 subtractions), the walking time in the stroke group increased further for both the forward walking (p=0.009) and backward walking tasks (p=0.018), but not for the obstacle-crossing task (p=1.000) (Supplementary Table 2). The control group was different in that the increase in walking time was significant only for the backward walking task (p=0.021) but not for the forward walking (p=0.223) or the obstacle-crossing task (p=1.000) as the difficulty level of the cognitive task was increased.

Dual-task effect on cognitive task performance

Significant main effects of the mobility task (stroke group: F=8.678, p < 0.001, η_p^2=0.126; control group: F=4.931, p=0.010, η_p^2=0.137) and cognitive task (stroke group: F=114.483, p<0.001, η_p^2=0.656; control group: F=40.927, p<0.001, η_p^2=0.569) were found in both groups (Figure 3A and 3B). The mobility task × cognitive task interaction was only significant in the stroke group (F=7.979, p<0.001, η_p^2=0.117) but not in the control group (F=1.884, p=0.126, η_p^2=0.057). In both groups, the CRR was significantly lower for serial-7 subtractions than for serial-3 subtractions in dual-task conditions, regardless of the difficulty level of the mobility task (p<0.001) (Supplementary Table 3).

In the stroke group, the CRR was significantly decreased only when obstacle-crossing (p=0.023) or backward walking (p<0.001) was imposed on the serial-3 subtraction task compared with the single-task condition. Such a dual-task effect on the CRR was not detected during the forward walking task (p=1.000) (Supplementary Table 3). The CRR for serial-7-subtractions was significantly decreased when the backward walking task was added (p<0.001), but not when the forward walking or obstacle-crossing task was added (p=1.000). In contrast, in the control group, the change in CRR of both serial-3 (p=0.022) and serial-7 subtractions (p=0.017) was significant only when the obstacle-crossing task was added.

Discussion

Our hypothesis was supported because we observed a significant interaction between the difficulty levels of the mobility and cognitive tasks in determining the degree of cognitive-motor interference in individuals with stroke. Additionally, the interference patterns were highly specific to the combination of the mobility and cognitive tasks used and were different from those in the control group.

Dual-task effect on walking time

Interference on walking performance (i.e., an increase in walking time) occurred in individuals with stroke when either the serial-3 subtraction or serial-7 subtraction task was imposed, regardless of the mobility task used. However, the interference effect was more pronounced when the complexity level of either the mobility task or the cognitive task increased (Figure 2A). Particularly, the combination of the backward walking and serial-7 subtraction task resulted in the most exaggerated increase in the walking time compared with the single-task condition, thereby accounting for the mobility task × cognitive task interaction effect.

There was a difference in dual-task effect on walking time between the stroke group and control group. As the cognitive task became more difficult (serial-7 vs. serial-3 subtractions), the increase in walking time during forward walking was only significant for the stroke group but not the control group (Supplementary Table 2). This was largely in line with the study by Hyndman et al., which found that adding a memory task (e.g., remembering a shopping list) to forward walking resulted in a more pronounced increase in walking time in the stroke group than healthy controls.[9] As previously mentioned, only one mobility task was used in their study. By using different mobility tasks, we were able to obtain a more comprehensive picture of the dual-task interference patterns. Our results demonstrated that the between-group difference in the dual-task interference effect on walking time was highly influenced by the difficulty level of the mobility and cognitive tasks used.

Dual-task effect on cognitive task performance

The dual-task interference effect on the performance of the cognitive task was also detected in individuals with stroke. The CRR of serial-3 subtractions was significantly decreased when obstacle-crossing or backward walking was imposed, and adding backward walking to serial-7 subtractions also led to a significant interference effect on CRR. Surprisingly, the dual-task effect on the CRR for serial-7 subtractions was not as pronounced as that for serial-3 subtractions and was only significant when backward walking was imposed (Figure 3). This may be because the CRR was already low during the single-task condition, leaving less room for a further decrease in the CRR during the dual-task condition. The dual-task effect on CRR in the stroke group was also different from that in the control group. In particular, the dual-task effect on CRR during backward walking was observed only in the stroke group but not in the control group (Supplementary Table 3 and Figure 3).

Few studies have assessed the dual-task effects on cognitive performance in individuals with stroke, and none of these studies have compared the difference between individuals with stroke and their peers without stroke. Our results are similar to those of Plummer-D'Amato et al. in that no significant decrease in the CRR was found when forward walking was performed concurrently with serial-3 subtractions compared with the single-task condition (Figure 3).[10] In contrast, Patel & Bhatt showed that the level of cognitive performance was reduced by 30% when a forward walking task was imposed during serial subtractions (counting backward).[1] The reason for the discordance in results may be related to the difference in characteristics of participants. Participants in Patel & Bhatt's study had a quicker walking speed (mean: 1.19 meters/second) under the single-task condition than those in Plummer-D'Amato et al.'s study (mean: 0.78 meters/second) and ours (mean: 0.69 meters/second).[1,10] Nevertheless, our results provided convincing evidence that adding a mobility task can produce interference effects on cognitive performance and that the magnitude of the effect was dependent upon the interaction between the difficulty level of the mobility and cognitive tasks and presence of stroke.

Task prioritization strategy

Our results also provided insight into the task prioritization strategies used as the dual-task conditions changed. In both groups, the increase in walking time was significant when the serial-3 subtraction or serial-7 subtraction task was added to forward walking compared with the single-task condition. However, the cognitive task performance was not significantly compromised. This was indicative of the phenomenon called cognitive-related motor interference, as described by Plummer et al.[3] More attentional resources were allocated to the serial subtraction task, which was not a typical task encountered in daily living; thus, participants may consider it a more difficult task. However, the decrease in walking performance was relatively modest (mean range: 2.9–4.1 seconds in individuals with stroke and 2.7-4.3 seconds in controls) during the dual-task condition (Supplementary Table 2), because forward walking was a relatively automatic task with a low difficulty level. This is similar to the study by Plummer-D'Amato et al., which reported a significant but modest (9%) dual-task effect on gait speed but no significant dual-task effect on the CRR when individuals with stroke performed serial subtractions concurrently with forward walking, indicating prioritization of the cognitive task.[10] Our results showed that this strategy was similar in both the stroke and control groups.

As the difficulty of the mobility task was increased to the next level (i.e., obstacle-crossing), we observed an interference effect on the CRR for serial-3-subtractions in both groups. However, the increase in walking time during the dual-task condition remained modest in both groups (mean range: 2.9–3.3 seconds in stroke, 3.2-3.8 seconds in controls) (Supplementary Table 2). It was very similar to that observed in the corresponding conditions during forward walking (mean range: 2.9–4.1 seconds in stroke, 2.7-4.3 seconds in controls). This indicated that participants may have allocated more attentional resources to the obstacle-crossing task to keep the motor cost constant despite the increased difficulty level of the mobility task. Consequently, the performance level of the cognitive task was compromised.

As the difficulty level of the mobility task was further increased (i.e., backward walking), the decrease in the CRR was accompanied by an exaggerated increase in walking time in the stroke group. This illustrated the phenomenon of mutual interference. The demand for attentional resources increased to the extent that sacrificing the cognitive performance could not adequately prevent the walking speed from decreasing further. On the other hand, a different strategy was used by the control group. When the dual-task effect on walking time became more pronounced, there was no significant dual-task effect on CRR (i.e., cognitive-related motor interference). This finding indicated that the control participants had again allocated more attentional resources to the cognitive task while sacrificing walking speed. The slowed gait speed observed in both groups may not necessarily be a negative phenomenon in this context. Rather, it may reflect an adaptive strategy to ensure safety in the face of a highly challenging dual-task condition.[3] This was particularly relevant for the stroke group because they were presumably at a higher risk of falls. As the walking ability of the stroke group was much poorer than the control group, they may require additional attentional resources to tackle the challenging walking task. This may be coupled with less overall available attentional resources owing to the brain injury sustained by the participants with stroke. This may explain why the stroke group was not able to maintain the cognitive performance despite a reduced walking speed.

Clinical and research implications

This study has important clinical and research implications. First, the phenomenon of cognitive-motor interference should merit more attention in stroke assessment. Specifically, the degree of interference and task prioritization strategy vary greatly with the type of mobility and cognitive tasks used. Therefore, the assessment should consider using various task combinations to capture a more comprehensive picture of the dual-task ability of different people after stroke. Second, more attention to the therapeutic efforts in reducing cognitive-motor interference or optimizing task prioritization is warranted. Studies on intervention strategies to reduce cognitive-motor interference after stroke are scarce. Most studies have major limitations, including the lack of proper controls, lack of measurement of dual-task performance, and small sample sizes (<20 participants).[37-41] The results of the present study and other related works on cognitive-motor interference post-stroke may provide the basis for creating intervention programs that address dual-task mobility function post-stroke. Good-quality randomized controlled trials are needed to evaluate the efficacy of these programs.

Limitations and future research directions

This study has several limitations. First, the results can only be generalized to individuals with chronic stroke who are independent in ambulation with normal cognition. Second, only mental tracking function was tested. The serial-3 and serial-7 subtraction tasks were chosen because they had been commonly used in previous studies on dual-task functions in other populations, and their reliability and validity had been established.[31,42-48] No gait parameter other than speed was measured. Different interference patterns may have been observed if other types of cognitive tasks or gait parameters (e.g., double-limb support, symmetry, etc.) were used.[10] Finally, there was a small difference in MoCA score between the stroke group and controls (1.3 points). However, the magnitude of difference was not clinically important as it was well below the minimal detectable difference value of MoCA (4 points).[49] Furthermore, there was no significant difference in the attention sub-scale score of MoCA. The performance in serial-3 and serial-7 subtractions under single-task conditions also was not significantly different between the two groups. Taken together, the level of cognitive ability as assessed by the measurement tools used in this study was very similar between the stroke group and control group. The small difference in MoCA score should not have any major impact on the interpretation of our results.

Conclusions

Significant dual-task interference affects mobility and mental tracking function after chronic stroke. The degree and pattern of dual-task interference were strongly associated with the difficulty levels of both the mobility and cognitive tasks and were different from individuals without a stroke history.

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Conflict of Interest Statement

The authors declare that there is no conflict of interest.

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Figure legends

Figure. 1 Obstacle course

Seven obstacles (length 80 cm, width 5 cm, height 4 cm) were placed along the middle 10 meters of the walkway, with a distance of 1.5 meters between the obstacles. There were two meters before and after the starting and finishing lines so that participants would have enough distance to accelerate and decelerate.

Figure. 2 Dual-task effect on walking time

The dual-task effect on walking time is shown for the stroke group (2A) and control group (2B). The walking time values (in seconds or s) recorded during a single-task condition (●), dual-task condition with serial-3 subtractions (■), and dual-task condition with serial-7 subtractions (▲) are displayed. Each error bar represents one standard error of the mean. *Significantly different from the same mobility task during a dual-task condition. †Significantly different between the serial-3 subtractions and serial-7 subtractions. In both groups, a significant interaction was found between the difficulty level of the mobility task and that of the cognitive task. As the cognitive task became more difficult (serial-7 vs. serial-3 subtractions), the increase in walking time during forward walking was only significant for the stroke group but not the control group.

Figure. 3 Dual-task effect on cognitive task performance

The dual-task effect on correct response rate (CRR) is shown for the stroke group (3A) and control group (3B). The CRRs for serial-3 subtractions during single-task and dual-task conditions are represented by closed (●) and open circles (○), respectively. The CRRs for serial-7 subtractions during single-task and dual-task conditions are represented by closed (■) and open squares (□), respectively. *Significantly different from the corresponding dual-task condition. †Significantly different between the serial-3 subtractions and serial-7 subtractions during the dual-task condition. A significant interaction was found between the difficulty level of the mobility task and that of the cognitive task in the stroke group, but not the control group. The dual-task effect on CRR during backward walking was observed only in the stroke group but not in the control group.