Effects of exergames and cognitive-motor dual-task training on cognitive, physical and dual-task functions in cognitively healthy older adults: An overview

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Effects of exergames and cognitive-motor dual-task training on cognitive, physical and dual-task functions in cognitively healthy older adults: an overview

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Abstract

This overview aims to summarize the effectiveness of cognitive-motor dual-task and exergame interventions on cognitive, physical and dual-task functions in healthy older adults, as well as the feasibility, safety, adherence, transfer and retention of benefits of these interventions. We searched for systematic reviews or meta-analyses assessing the effects of cognitive-motor dual-task and exergame interventions on cognitive, physical and dual-task functions in cognitively healthy older adults through eight databases (CDSR (Cochrane), MEDLINE (PubMed), Scopus, EMBASE, CINAHL, PsycINFO, ProQuest and SportDiscus). Two reviewers performed the selection, data extraction and risk of bias evaluation independently (PROSPERO ID: CRD42019143185). Eighteen reviews were included in this overview. Overall, positive effects of cognitive-motor dual-task interventions on cognitive, physical and dual-task functions, as well as exergames on cognitive functions only, were observed in cognitively healthy older adults. In contrast, the effects of exergames on physical functions are more controversial, and their effects on dual-task functions have not been studied. The feasibility, safety, adherence, transfer and retention of benefits for both intervention types are still unclear. Future studies should follow more rigorous methodological standards in order to improve the quality of evidence and provide guidelines for the use of cognitive-motor dual-task and exergame interventions in older adults.

Keywords

Dual-task training; Exergame; Healthy older adults; Cognitive functions; Physical functions.

1. Introduction

Aging is associated with a high risk of physical and cognitive impairment, which contributes to disability and possible loss of independence (Anton et al., 2015). A cognitive-motor dual-task (CMDT) is defined as the simultaneous completion of a cognitive and a motor task (Montero-Odasso et al., 2012; Yogev-Seligmann et al., 2008). Cognitive-motor interference is defined as the overwhelming of attention abilities, resulting in a decrease in one or both tasks' performances. Aging is associated with increased risk of falling with the decrease in motor and cognitive functions, or the increase of cognitive-motor interference (Montero-Odasso et al., 2012; Yogev-Seligmann et al., 2008). Thus, the maintenance of cognitive, physical and CMDT capabilities seems to be an important way of preserving autonomy through aging.

Many recent studies have used interventions requiring the realization of a motor and a cognitive task, performed sequentially or simultaneously to improve CMDT functions (Tait et al., 2017). Exergames (EGs) are increasingly being developed and are often studied together with other CMDT modalities (Schoene et al., 2014; Wollesen & Voelcker-Rehage, 2014). EGs are videogames played on a digital device, including a wide range of interfaces (Baranowski et al., 2008) that require physical activity (Vázquez et al., 2018) as well as cognitive tasks when played (e.g. considering the continuous feedback and making quick decisions) (Larsen et al., 2013). EGs are characterized by their potential ability to motivate older participants to practice through an attractive, interactive way (Skjæret et al., 2016).

Many reviews have tried to synthesize the results of CMDT and EG interventions (Agmon et al., 2014; Stojan & Voelcker-Rehage, 2019), but those reviews show great heterogeneity related to intervention (content, duration and modality), comparison (active or inactive control groups) and outcome (cognitive, physical or dual-task functions). Moreover, the results are controversial as interventions were found to be effective (Agmon et al., 2014), ineffective (Donath et al., 2016) and unclear (Stojan & Voelcker-Rehage, 2019) across different studies. A recent overview has summarized the positive effects of EGs on physical functions in cognitively healthy older adults (Reis et al., 2019), but the effectiveness of EG interventions on cognitive and dual-task functions in older adults is still to be determined.

At the same time, most intervention studies assess feasibility, long term effects, safety and adherence, but this information seems unclear for CMDT and EG interventions in older adults (Ghai et al., 2017; Kappen et al., 2019).

This overview is aimed at 1) summarizing the effects of CMDT and EG interventions on cognitive, physical and dual-task functions in cognitively healthy older adults, and 2) determining the feasibility, safety, adherence, transfer and retention of improvements in these interventions.

2. Methods

2.1. Design and protocol

We used the definition of "systematic review" from a Cochrane guide (Chandler et al., 2017). In order to perform this overview, we used a protocol established prior to the conduct of the review that was registered on PROSPERO (registration ID: CRD42019143185). The design and the protocol of this overview were established following authors' recommendations (Pollock et al., 2016), checklist (Bougioukas et al., 2018), Cochrane guidelines (Pollock et al.,

2018) and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al., 2009).

2.2. Search strategy

In order to gather the maximum amount of literature, and not to miss any reviews, we conducted our overview through different online databases: the Cochrane Database of Systematic Reviews, MEDLINE (PubMed search engine), Scopus, EMBASE, CINAHL, PsycINFO, ProQuest and SportDiscus. We also searched for grey literature through the reference list of included reviews, and consulted content experts (Louis Bherer and Bradford J. McFadyen). We performed the entire search from June to August 30, 2019. We searched the titles, keywords and abstracts of database entries by using a keyword search: older adults AND cognitive-motor dual-task training OR exergame AND physical OR cognitive OR dual-task functions (see details in **Appendix A**).

2.3. Eligibility criteria and selection

Two authors (MGG and AP) conducted the eligibility analysis and selection of reviews for inclusion in this overview independently; in case of disagreement or ambiguity, a third author decided (SM). Concerning the study design, the inclusion criteria were systematic reviews or meta-analyses, including randomized controlled trials (RCTs) or non-randomized studies of interventions (NRSIs), and full scientific papers all written in English. To define the study content's eligibility, we used the PICO framework (Population, Intervention, Comparison, Outcome) (Schardt et al., 2007). The inclusion criteria were systematic reviews assessing as primary outcome the CMDT's effect on cognitive, physical or dual-task functions and EG interventions compared to cognitive or motor single-task trainings, fall prevention programs or no interventions conducted on cognitively healthy older adults. Fall prevention programs are trainings following recommendations for the prevention of falls in older adults (Nelson et al., 2007). The physical outcomes encompass motor capacities (strength, gait, mobility, postural control and balance), and falls. The cognitive outcomes encompass learning, memory, executive functions, processing speed, visuospatial capabilities, attention, reaction time and overall cognition. The dual-task functions encompass any combined cognitive and physical functions performed simultaneously. The exclusion criteria were: i) non-systematic reviews; ii) reviews integrating participants with neurological diseases (e.g. mild cognitive impairment, dementia, stroke, Alzheimer's or Parkinson's disease) or young participants (below 60 years old); iii) reviews that only included motor dual-tasks, sequential cognitive-motor training or passive video games. After removing duplicates and scanning titles and abstracts, eligible studies were screened for inclusion by thorough reading.

2.4. Data extraction

Two authors (MGG and AP) independently extracted data from the reviews included: number of primary studies included, objectives, populations, interventions, comparisons, outcomes, conclusion, risk of bias, feasibility (centre or home based, grouped or individual interventions, supervision), safety, adherence, transfer and retention of benefits. In case of disagreement or ambiguity, a third author decided (SM).

2.5. Study quality assessment

Two authors (MGG and AP) independently rated the methodology quality of the reviews included using the AMSTAR-2 critical appraisal tool (Shea et al., 2017). Any disagreements were recorded to assess the agreement rate and then resolved by a third author (SM).

2.6. Overlap

The different systematic reviews included in this overview may have used the same primary studies, at least partially; this is called overlap. It is necessary to calculate the corrected covered area (CCA) (Pieper et al., 2014) to avoid the risk of interpretation and conclusion errors, giving disproportionate power to multiple primary studies.

3. Results

3.1. Characteristics of the reviews included

The initial database search revealed 4243 potentially relevant reviews. After duplicate reviews were removed, 2815 titles and abstract were screened. A total of 62 reviews were assessed as full text, and 18 were included in this overview (**Figure A**). The list of excluded reviews and reasons for exclusion are available in **Appendix B**. The eighteen reviews (Agmon et al., 2014; Bleakley et al., 2015; Choi et al., 2017; Donath et al., 2016; Joubert & Chainay, 2018; Larsen et al., 2013; Laufer et al., 2014; Levin et al., 2017; Molina et al., 2014; Neri et al., 2017; Plummer et al., 2015; Rodrigues et al., 2014; Schoene et al., 2014; Stojan & Voelcker-Rehage, 2019; Taylor et al., 2018; Wang et al., 2015; Wollesen & Voelcker-Rehage, 2014; Zhu et al., 2016) were published in the last six years, including eight reviews with additional meta-analyses (Donath et al., 2016; Neri et al., 2017; Plummer et al., 2015; Rodrigues et al., 2014; Taylor et al., 2018; Wang et al., 2015; Zhu et al., 2016). The CCA value was 0.05, so the overlap can be considered as slight (see the details of overlap in **Appendix C**).The eighteen reviews included 203 singular primary articles (i.e. which did not overlap).

Figure A: flow chart

3.1.1. Participants and interventions

The characteristics of the 18 systematic reviews included are summarized in **Table A**. These reviews included cognitively healthy older adults (Joubert & Chainay, 2018; Larsen et al., 2013; Laufer et al., 2014; Levin et al., 2017; Molina et al., 2014; Rodrigues et al., 2014; Stojan & Voelcker-Rehage, 2019; Wang et al., 2015; Zhu et al., 2016), or with balance impairment or history of falls (Agmon et al., 2014; Bleakley et al., 2015; Choi et al., 2017; Donath et al., 2016; Neri et al., 2017; Plummer et al., 2015; Schoene et al., 2014; Taylor et al., 2018; Wollesen & Voelcker-Rehage, 2014). Participants were 60 years old or older, with average ages in primary studies ranging from 60 (Stojan & Voelcker-Rehage, 2019) to 91 years old (Plummer et al., 2015). Eight reviews did not report the mean age of participants within the studies they included (Joubert & Chainay, 2018; Molina et al., 2014; Neri et al., 2017; Rodrigues et al., 2014; Schoene et al., 2014; Taylor et al., 2018; Wang et al., 2015; Wollesen & Voelcker-Rehage, 2014). After examination of the overlap, so by considering each study included in the reviews only once, the actual number of participants included was 28446.

Table A: Characteristics of the reviews included

Seven of the reviews included assessed the efficacy of CMDTs (Agmon et al., 2014; Joubert & Chainay, 2018; Levin et al., 2017; Plummer et al., 2015; Wang et al., 2015; Wollesen & Voelcker-Rehage, 2014; Zhu et al., 2016), and eleven assessed EG interventions (Bleakley et al., 2015; Choi et al., 2017; Donath et al., 2016; Larsen et al., 2013; Laufer et al., 2014; Molina et al., 2014; Neri et al., 2017; Rodrigues et al., 2014; Schoene et al., 2014; Stojan & Voelcker-Rehage, 2019; Taylor et al., 2018). Reviews were classified according to their actual interventions, not their titles (e.g. Schoene et al., 2014). CMDT interventions systematically included a cognitive (attention, memory, executive functions, processing speed, visuospatial capabilities or overall cognition) and a physical task (strength, gait, mobility, postural control or balance training). EG interventions used mostly commercial video games (Wii ®, Kinect ®, Dance Dance Revolution ® and virtual reality equipment). Studies amongst reviews sometimes used non-commercial, specially designed games, such as cybercycle (Larsen et al., 2013; Stojan & Voelcker-Rehage, 2019), cyberstep (Neri et al., 2017; Stojan & Voelcker-Rehage, 2019) or computerized balance training (Bleakley et al., 2015; Schoene et al., 2014; Taylor et al., 2018).

The characteristics of the interventions are summarized in **Table A**. Program characteristics were heterogeneous within and between each review included, with respect to frequency (1 to 3 times a week), length (15 to 90 minutes) and duration (once to 96 weeks). The cognitive and physical tasks were either asked simultaneously only (i.e., dual-task training) (Bleakley et al., 2015; Choi et al., 2017; Donath et al., 2016; Larsen et al., 2013; Laufer et al., 2014; Molina et al., 2014; Neri et al., 2017; Rodrigues et al., 2014; Stojan & Voelcker-Rehage, 2019; Taylor et al., 2018) or both simultaneously and sequentially (i.e., sequential cognitive-motor training) (Joubert & Chainay, 2018; Levin et al., 2017; Plummer et al., 2015; Zhu et al., 2016) within reviews; some did not specify this modality (Agmon et al., 2014; Schoene et al., 2014; Wang et al., 2015; Wollesen & Voelcker-Rehage, 2014). Sequential cognitive-motor trainings combined physical and cognitive separately (e.g., Oswald et al., 2006, cited in Zhu et al., 2016). The mode of release was reported in six reviews: CMDT interventions were mostly distributed in groups (Agmon et al., 2014; Plummer et al., 2015; Zhu et al., 2016), and EGs were mostly distributed individually (Laufer et al., 2014; Molina et al., 2014; Taylor et al., 2018). The setting was only reported in three EG reviews (Choi et al., 2017; Schoene et al., 2014; Taylor et al., 2018) and interventions were mostly not home-based (gymnasium, clinical or research centre).

CMDTs and EGs were compared to inactive and active control groups (single-task training or fall prevention programs) (Agmon et al., 2014; Bleakley et al., 2015; Choi et al., 2017; Donath et al., 2016; Joubert & Chainay, 2018; Larsen et al., 2013; Laufer et al., 2014; Molina et al., 2014; Neri et al., 2017; Plummer et al., 2015; Rodrigues et al., 2014; Schoene et al., 2014; Stojan & Voelcker-Rehage, 2019; Taylor et al., 2018; Wang et al., 2015; Zhu et al., 2016), with or without placebo (Laufer et al., 2014; Molina et al., 2014; Taylor et al., 2018) or education (Agmon et al., 2014; Bleakley et al., 2015; Plummer et al., 2015; Zhu et al., 2016). . The content of active control groups is similar, involving one or more functions training in the same domain (cognitive or motor) carried out sequentially and separately (e.g., "fall prevention programs" include muscle strength, mobility, balance and reaction time exercises)

3.2. Results of individual studies

The efficacy of CMDT and EG interventions on cognitive, physical and dual-task functions, and their comparison with active or inactive control groups, are summarized in **Table A** and illustrated in **Figure B**.

Figure B: Summary of findings

3.2.1. Effectiveness of CMDT interventions on cognitive, physical and dual-task functions

Compared to fall prevention programs, single-task training, active and inactive control, two reviews found CMDT interventions superior (Joubert & Chainay, 2018; Levin et al., 2017), and one was found equivalent (Zhu et al., 2016) in improving cognitive functions. Cognitive outcomes varied, including attention, memory, executive functions, processing speed, visuospatial capabilities and overall cognition (Table A).

Compared to fall prevention programs, single-task training, motor-motor dual-task training, active and inactive control, one review found CMDT interventions superior (Wang et al., 2015), and one was found equivalent (Levin et al., 2017) in improving physical functions. Physical outcomes varied, including motor capacities (strength, gait, mobility, postural control and balance), and falls (rates, risk factors, fear) (Table A).

Three reviews assessed the effectiveness of CMDT interventions on dual-task capabilities in healthy older adults (Agmon et al., 2014; Plummer et al., 2015; Wollesen & Voelcker-Rehage, 2014), and found superior effects compared to single-task training in improving postural control, balance, mobility and gait during dual-task conditions (Table A).

It is worth noting that, for all the functions studied, CMDT interventions' effects were greater than for the inactive control group, and greater than or equal to the active control group.

3.2.2. Feasibility, safety, adherence, transfer and retention of CMDT interventions

One review reported the supervision in CMDT interventions, and the result was unclear (Agmon et al., 2014). The assessment of the safety of interventions was conducted through the occurrence of adverse events. The only review evaluating CMDT intervention safety reported no serious adverse events (Wang et al., 2015). Adherence has rarely been studied in CMDT interventions, but presented acceptable compliance and drop-out rates (Wollesen & Voelcker-Rehage, 2014). The assessment of the transfer of benefits encompasses several factors, and was only reported in four CMDT intervention reviews (Agmon et al., 2014; Joubert & Chainay, 2018; Wollesen & Voelcker-Rehage, 2014; Zhu et al., 2016). CMDT interventions induced positive (Joubert & Chainay, 2018) or unclear (Zhu et al., 2016) effects on daily living activities and mixed effects on tasks other than those trained for (Agmon et al., 2014; Wollesen & Voelcker-Rehage, 2014). Long-term benefits were only reported in three CMDT intervention reviews (Agmon et al., 2014; Joubert & Chainay, 2018; Zhu et al., 2016). Benefits persisted from two weeks (Agmon et al., 2014) to five years (Joubert & Chainay, 2018).

3.2.3. Effectiveness of EG interventions on cognitive and physical functions

One review found EG interventions effective on cognitive functions (Bleakley et al., 2015). Two reviews found that EG interventions were equivalent compared to fall prevention programs, single-task training and active and inactive controls (Schoene et al., 2014; Stojan & Voelcker-Rehage, 2019). Cognitive outcomes varied, including attention, memory, executive functions, processing speed, visuospatial capabilities and overall cognition (Table A).

The effectiveness of EG interventions on physical functions was unclear (Bleakley et al., 2015; Molina et al., 2014; Rodrigues et al., 2014). Compared to fall prevention programs, single-task training, motor-motor dual-task training and active and inactive controls, two reviews found EG interventions superior (Neri et al., 2017; Taylor et al., 2018), and four were found equivalent (Choi et al., 2017; Larsen et al., 2013; Laufer et al., 2014; Schoene et al., 2014) in improving physical functions. One review found higher benefits for single-task training compared to EGs in cognitively healthy older adults (Donath et al., 2016). Physical outcomes varied, including motor capacities (strength, gait, mobility, postural control and balance), and falls (rates, risk factors, fear) (Table A).

No review assessed the effectiveness of EG interventions on dual-task functions.

It is worth noting that for all the functions studied, the effects of EG interventions were greater than for the inactive control group, and greater than or equal to the active control group.

3.2.4. Feasibility, safety, adherence, transfer and retention of EG interventions

EG interventions were mostly supervised (Donath et al., 2016; Laufer et al., 2014; Molina et al., 2014; Schoene et al., 2014; Stojan & Voelcker-Rehage, 2019; Taylor et al., 2018), or the use of supervision was unclear (Bleakley et al., 2015). Concerning safety, EG interventions induced no (Bleakley et al., 2015; Laufer et al., 2014; Molina et al., 2014) or rare adverse events (Taylor et al., 2018). The assessment of adherence to EG interventions encompassed several factors, such as appeal, enjoyment or completion. Thus, appeal and enjoyment (Bleakley et al., 2015; Molina et al., 2014; Taylor et al., 2018) were good. Completion and compliance were high (Bleakley et al., 2015; Laufer et al., 2014; Taylor et al., 2018; Stojan & Voelcker-Rehage, 2019), while the drop-out rate was very low (Larsen et al., 2013). No reviews reported transfers or retention of benefits for EG interventions.

3.2.5. Methodological quality, risk of bias, quality of evidence and funding

The reviews included used different tools to assess the methodological quality of the primary studies included: the Cochrane collaboration risk of bias tool (Bleakley et al., 2015; Larsen et al., 2013; Neri et al., 2017; Stojan & Voelcker-Rehage, 2019; Taylor et al., 2018), the Physiotherapy Evidence Database scale (Donath et al., 2016; Joubert & Chainay, 2018; Laufer et al., 2014; Molina et al., 2014; Wang et al., 2015), the Jadad scale (Levin et al., 2017; Rodrigues et al., 2014), the Downs and Black scale (Plummer et al., 2015), the Portney and Watkins score (Agmon et al., 2014), and personal or modified scales (Schoene et al., 2014; Wollesen & Voelcker-Rehage, 2014; Zhu et al., 2016). The quality of the primary studies included was low to high (see details in **Table A**).

Details of the AMSTAR-2 assessment of methodological quality are presented in **Table B**. Two overview authors (MGG and AP) agreed at 87% in their rating across the 18 systematic reviews included. The overall quality of the systematic reviews included was "critically low", with a 6/16 mean score.

Six reviews reported a source of funding (Choi et al., 2017; Larsen et al., 2013; Rodrigues et al., 2014; Stojan & Voelcker-Rehage, 2019; Wang et al., 2015; Zhu et al., 2016), and all authors declared no conflicts of interests (**Appendix D**).

Table B: methodological quality of the reviews included

4. Discussion

The present overview aimed to summarize the effects of CMDT and EG interventions on cognitive, physical and dual-task functions in healthy older adults, as well as the feasibility, safety, adherence, transfer and retention of benefits of these interventions. Overall, the eighteen reviews included in this overview highlighted positive effects of CMDT interventions on cognitive, physical and dual-task functions, and EGs on cognitive outcomes. However, this overview also highlighted controversial elements, such as the effects of EG interventions on physical functions. Lastly, the effects of EG interventions on dual-task outcomes, as well as safety, adherence, transfer and retention of benefits, remain understudied for both types of intervention.

4.1. Cognitive-Motor Dual-Task (CMDT) interventions

Compared to single-task, fall prevention programs or no intervention, CMDT intervention effects were found: i) superior (Joubert & Chainay, 2018; Levin et al., 2017) or equivalent (Zhu et al., 2016) on cognitive function; ii) superior (Wang et al., 2015) or equivalent (Levin et al., 2017) on physical functions and iii) superior on dual-task functions (Agmon et al., 2014; Plummer et al., 2015; Wollesen & Voelcker-Rehage, 2014). CMDTs can be recommended to improve cognitive, physical and dual-task functions in cognitively healthy older adults. CMDT interventions were mostly distributed in groups (Agmon et al., 2014; Plummer et al., 2015; Zhu et al., 2016), which would be as effective as individual sessions (Agmon et al., 2014) and less time-consuming.

The transfer of benefits of CMDT interventions on tasks other than those trained for or daily living activities was varied, with positive (Joubert & Chainay, 2018), mixed (Agmon et al., 2014; Wollesen & Voelcker-Rehage, 2014) or unclear results (Zhu et al., 2016). This may be

due to the lack of measurement tools to assess early changes in daily living activities or functional tests (Bruderer-Hofstetter et al., 2018).
The long-term benefits of CMDT interventions is understudied, even though it looks promising. (Agmon et al., 2014; Joubert & Chainay, 2018; Zhu et al., 2016). Through these reviews, nine articles included a follow-up period and reported a good retention of benefits. This retention varied from two weeks (Agmon et al., 2014) to five years (Joubert & Chainay, 2018); even though it could be discussed whether a persistence of effect of two weeks is "long-term".

The need for supervision, safety, home-based feasibility and adherence to CMDT interventions were almost never reported in reviews, while we know from the literature that the major obstacle to exercise interventions in older adults is often weak participation and adherence (Nyman & Victor, 2012).

4.2. Exergame (EG) interventions

EG interventions were found effective on cognitive functions (Bleakley et al., 2015) and equivalent to single-task, fall prevention programs or no intervention (Schoene et al., 2014; Stojan & Voelcker-Rehage, 2019).
Conversely, the effectiveness of EG interventions on physical functions in older adults is unclear (Bleakley et al., 2015; Molina et al., 2014; Rodrigues et al., 2014). Moreover, compared to single-task, fall prevention programs or no intervention, reviews found EG interventions superior (Neri et al., 2017; Taylor et al., 2018), equivalent (Choi et al., 2017; Larsen et al., 2013; Laufer et al., 2014; Schoene et al., 2014) or less effective (Donath et al., 2016). Thus, EGs cannot be considered as an alternative intervention for improving physical

functions in cognitively healthy older adults. This might be due to the lack of control of the difficulty or intensity of the physical task (Lauenroth et al., 2016; Wollesen & Voelcker-Rehage, 2014).

It seems that authors have so far assessed the impact of EG interventions on physical functions more than on cognitive functions, with the induced cognitive task being considered as “secondary” (Larsen et al., 2013). This could be reconsidered in view of recent results showing an effect of EGs on cortical activity (Anders et al., 2018). When interventions were directly compared, however, EGs were found more effective than CMDTs on cognitive functions in healthy older adults (Bruderer-Hofstetter et al., 2018; Lord & Close, 2018).

The effects of EG interventions on dual-task functions have never been reported in reviews. It is surprising that interventions including dual-tasks did not systematically have dual-task functions as their outcome. This may be due to the lack of standardized functional assessments for cognitive-motor dual-tasks (Agmon et al., 2014; Plummer et al., 2015; Wollesen & Voelcker-Rehage, 2014).

EG interventions were mostly distributed individually (Laufer et al., 2014; Molina et al., 2014; Taylor et al., 2018). This may be due to the experimental need for supervision and the game support used.

Most reviews reported supervised EG interventions (Donath et al., 2016; Laufer et al., 2014; Molina et al., 2014; Schoene et al., 2014; Stojan & Voelcker-Rehage, 2019; Taylor et al., 2018), and this does not provide sufficient information to establish whether EG interventions can be recommended for unsupervised home use (Howes et al., 2017). However, systematic reviews reported satisfactory effectiveness and feasibility for exercise-based games interventions in home settings for healthy (Miller et al., 2014) or neurologically impaired (Perrochon et al., 2019) older adults.

The safety (Bleakley et al., 2015; Laufer et al., 2014; Molina et al., 2014; Taylor et al., 2018) and adherence (Bleakley et al., 2015; Larsen et al., 2013; Laufer et al., 2014; Molina et al., 2014; Stojan & Voelcker-Rehage, 2019; Taylor et al., 2018; Wollesen & Voelcker-Rehage, 2014) during EG interventions were good when assessed, but only reported in a few studies in this reviews. This is promising, EG being considered even more enjoyable than traditional interventions (Choi et al., 2017).

The transfer and long-term effects of EGs were mostly not reported, whereas they are needed to propose the best possible interventions. It is worth noting that many authors highlighted the lack of long-term assessment (Larsen et al., 2013; Laufer et al., 2014; Molina et al., 2014; Plummer et al., 2015; Wang et al., 2015).

Lastly, an unclear parameter is the use of commercial or non-commercial games. Commercial videogames such as Nintendo Wii ® or Xbox Kinect ® have already been introduced as alternatives in rehabilitation (Bonnechère et al., 2016) and balance training (Pietrzak et al., 2014). Commercial videogames are relatively inexpensive when compared with custom-developed rehabilitation tools, but less adapted (Laufer et al., 2014). They are not developed to specifically improve clinical outcomes and present a lack of task-specificity and progressive overload (Schoene et al., 2014). It has been reported that some dropouts were due to task complexity (Bleakley et al., 2015).

4.3. Common to CMDT and EG interventions

The positive results for CMDT and EG interventions should be interpreted carefully, because all included reviews with low or critically low methodological quality (**Table B**).

The purpose of this overview was not to assess the most prolific intervention conditions. However, "recommendations" emerge from the literature included. For the most effective interventions on cognitive outcomes, one should focus on general rather than specific dual-task training (Lipardo et al., 2017; Wollesen & Voelcker-Rehage, 2014), individual or group-based (Agmon et al., 2014; Bruderer-Hofstetter et al., 2018) with increasing difficulty (Wollesen & Voelcker-Rehage, 2014) of demanding tasks (Lauenroth et al., 2016), integrating feedback (Lauenroth et al., 2016; Wollesen & Voelcker-Rehage, 2014) and step training (Lord & Close, 2018; Schoene et al., 2014). For the most effective interventions on physical outcomes, one should focus on general rather than specific dual-task training (Lipardo et al., 2017; Wollesen & Voelcker-Rehage, 2014), demanding tasks (Lauenroth et al., 2016; Wollesen & Voelcker-Rehage, 2014) with increasing difficulty (Wollesen & Voelcker-Rehage, 2014) and variable rather than fixed priority tasks (Agmon et al., 2014; Wollesen & Voelcker-Rehage, 2014) including step training (Lord & Close, 2018; Schoene et al., 2014). In order to maximize the transfer effect, one should focus on variable (Lussier et al., 2017; Wollesen & Voelcker-Rehage, 2014) and simultaneous task training (Wollesen & Voelcker-Rehage, 2014), including functional exercises (Bruderer-Hofstetter et al., 2018). The optimal dose of the interventions (length, frequency and duration) could not be established because every intervention seemed effective despite the great variability in modalities and outcomes both within and between reviews. While the dose was not a moderator according to one review (Vázquez et al., 2018), other authors indicated an efficacy for short programs (i.e. 40 minutes per week) (Agmon et al., 2014) or superior to 150 minutes per week (Howes et al., 2017). Also, it seems that the interventions should not be too frequent (i.e. less than five times per week), so as not to cause fatigue (Zhu et al., 2016).

The reviews included suggest that plasma brain-delivered neurotrophic factor (BDNF) and structural brain plasticity variations induced by CMDT and EG interventions need to be explored (Levin et al., 2017; Stojan & Voelcker-Rehage, 2019). Indeed, the effects of physical activity on neuroplasticity facilitation (i.e. increasing BDNF) are limited in time and return to baseline 10-60 minutes after the physical activity (Knaepen et al., 2010). This might explain why simultaneous CMDT interventions were found more effective than sequential interventions for cognitively healthy older adults (Tait et al., 2017), inducing synergistic cognitive effects (Fissler et al., 2013) and affecting neuroplasticity additively (Bamidis et al., 2014; Bherer, 2015).

4.4. Limits

The first limit of this overview is the low methodological quality and high risk of bias of the reviews included and the primary literature within these reviews. The evaluation tools for risk of bias and rates for the primary literature differed through the different studies included. The AMSTAR-2 we used showed an overall critically low confidence in the results of the reviews included, even though seven of them followed PRISMA or Cochrane Guidelines (Donath et al., 2016; Larsen et al., 2013; Laufer et al., 2014; Neri et al., 2017; Plummer et al., 2015; Stojan & Voelcker-Rehage, 2019; Zhu et al., 2016). A possible explanation is how the grid was read and interpreted. AMSTAR-2 integrates a new system with critical domains. For instance, the 7th item (“providing the list of excluded studies”) was reported as “No” in 83% of the reviews included, dropping their assessment to at least "low" (see Table B). We have realised a simulation of this evaluation without the 7th and the 13th items. The overall confidence in the results of the reviews would then be mostly "moderate" or "low".

In addition, the classification of reviews was sometime difficult. For example, the review from Schoene et al. indicates “cognitive-motor training” in the title, but actually deals with EGs; we therefore chose to classify it as EG interventions. On the other hand, the review from

Joubert et al. contains a single study using EG. In order not to provide conclusions on the effectiveness of EGs using a review of which one study out of fifty-two used Wii for its intervention, we therefore chose to classify it among CMDT interventions.

Lastly, as the interventions were multicomponent, it is difficult to fully identify which of the cognitive or physical tasks were the “active ingredients”, or whether it was a combination that provided the effects (Booth et al., 2016). Furthermore, the clinical scales used only provided an overall assessment, and not information on specific aspects or underlying mechanisms (Choi et al., 2017). Moreover, one cannot reach the same intensity levels during a dual-task training as during separate tasks (single-task or sequential training) (Joubert & Chainay, 2018). It is even possible that older people prioritize physical over cognitive tasks, which might be explained by wanting to protect oneself from falls (Schaefer & Schumacher, 2011). It thus seems important to propose interventions with suitable physical and cognitive loads, ensuring that neither task takes precedence over the other.

4.5. Futures studies

Since the effectiveness of CMDT interventions on cognitive, physical and dual-task functions, and EGs on cognitive functions in cognitively healthy older adults were demonstrated, it is necessary to focus on that which is unclear, specifically the effectiveness of EG interventions on physical and dual-task functions, as well as the transfer and retention of benefits and the feasibility of both interventions (i.e. the optimum dose, the need for supervision, the need for group or individual sessions, safety and adherence). Further research should also focus on the need for task prioritization (Kelly et al., 2013; Yogev-Seligmann et al., 2010) in order to counterbalance avoidance strategies (Schaefer & Schumacher, 2011). Moreover, further research should focus on comparing the use of patient-oriented EGs with the use of commercial games. Lastly, CMDTs and EGs seem to be promising interventions with cognitively-impaired older adults (Bruderer-Hofstetter et al., 2018; Gheysen et al., 2018), but it would be relevant to explore this. Similarly, other types of CMDTs should be studied, such as mind-body exercises (i.e. tai-chi, dance, martial arts) (Booth et al., 2016; Bruderer-Hofstetter et al., 2018; Gheysen et al., 2018).

5. Conclusion

This present overview found positive effects of CMDT interventions on cognitive, physical and dual-task functions, and positive effects of EG interventions on cognitive functions in cognitively healthy older adults. These results should be interpreted carefully, considering their critically low average methodological quality. Future research should focus on the effects of EG interventions on physical and dual-task functions. Home-based feasibility, adherence, optimal dose, retention and transfer of benefits of these interventions, and the possible need for custom made EGs, are also still to be determined. Further individual studies should follow recommendations and more rigorous methodological standards in order to improve the quality of the evidence and provide guidelines for the use of CMDT and EG interventions in older adults.

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References

Agmon, M., Belza, B., Nguyen, H. Q., Logsdon, R., & Kelly, V. E. (2014). A systematic review of interventions conducted in clinical or community settings to improve dual-task postural control in older adults. *Clinical Interventions in Aging*, 477. https://doi.org/10.2147/CIA.S54978

Anders, P., Lehmann, T., Müller, H., Grønvik, K. B., Skjæret-Maroni, N., Baumeister, J., & Vereijken, B. (2018). Exergames Inherently Contain Cognitive Elements as Indicated by Cortical Processing. *Frontiers in Behavioral Neuroscience*, *12*. https://doi.org/10.3389/fnbeh.2018.00102

Anton, S. D., Woods, A. J., Ashizawa, T., Barb, D., Buford, T. W., Carter, C. S., Clark, D. J., Cohen, R. A., Corbett, D. B., Cruz-Almeida, Y., Dotson, V., Ebner, N., Efron, P. A., Fillingim, R. B., Foster, T. C., Gundermann, D. M., Joseph, A.-M., Karabetian, C., Leeuwenburgh, C., … Pahor, M. (2015). Successful aging: Advancing the science of physical independence in older adults. *Ageing Research Reviews*, *24*, 304–327. https://doi.org/10.1016/j.arr.2015.09.005

Bamidis, P. D., Vivas, A. B., Styliadis, C., Frantzidis, C., Klados, M., Schlee, W., Siountas, A., & Papageorgiou, S. G. (2014). A review of physical and cognitive interventions in aging. *Neuroscience & Biobehavioral Reviews*, *44*, 206–220. https://doi.org/10.1016/j.neubiorev.2014.03.019

Baranowski, T., Buday, R., Thompson, D. I., & Baranowski, J. (2008). Playing for Real: Video Games and Stories for Health-Related Behavior Change. *American Journal of Preventive Medicine*, *34*(1), 74-82.e10. https://doi.org/10.1016/j.amepre.2007.09.027

Bherer, L. (2015). Cognitive plasticity in older adults: Effects of cognitive training and physical exercise. *Annals of the New York Academy of Sciences*, *1337*, 1–6. https://doi.org/10.1111/nyas.12682

Bleakley, C. M., Charles, D., Porter-Armstrong, A., McNeill, M. D. J., McDonough, S. M., & McCormack, B. (2015). Gaming for health: A systematic review of the physical and cognitive effects of interactive computer games in older adults. *Journal of Applied Gerontology: The Official Journal of the Southern Gerontological Society*, *34*(3), NP166-189. https://doi.org/10.1177/0733464812470747

Bonnechère, B., Jansen, B., Omelina, L., & Van Sint Jan, S. (2016). The use of commercial video games in rehabilitation: A systematic review. *International Journal of Rehabilitation Research. Internationale Zeitschrift Fur Rehabilitationsforschung. Revue Internationale De Recherches De Readaptation*, *39*(4), 277–290. https://doi.org/10.1097/MRR.0000000000000190

Booth, V., Hood, V., & Kearney, F. (2016). Interventions incorporating physical and cognitive elements to reduce falls risk in cognitively impaired older adults: A systematic review. *JBI Database of Systematic Reviews and Implementation Reports*, *14*(5), 110–135. https://doi.org/10.11124/JBISRIR-2016-002499

Bougioukas, K. I., Liakos, A., Tsapas, A., Ntzani, E., & Haidich, A.-B. (2018). Preferred reporting items for overviews of systematic reviews including harms checklist: A pilot tool to be used for balanced reporting of benefits and harms. *Journal of Clinical Epidemiology*, *93*, 9–24. https://doi.org/10.1016/j.jclinepi.2017.10.002

Bruderer-Hofstetter, M., Rausch-Osthoff, A.-K., Meichtry, A., Münzer, T., & Niedermann, K. (2018). Effective multicomponent interventions in comparison to active control and no interventions on physical capacity, cognitive function and instrumental activities of daily living in elderly people with and without mild impaired cognition – A systematic review and network meta-analysis. *Ageing Research Reviews*, *45*, 1–14. https://doi.org/10.1016/j.arr.2018.04.002

Chandler, J., Higgins, J., Deeks, J., Davenport, C., & Clarke, M. (2017). Chapter 1: Introduction. In *Cochrane Handbook for Systematic Review of Intervention version 5.2.0* (Cochrane).

Choi, S. D., Guo, L., Kang, D., & Xiong, S. (2017). Exergame technology and interactive interventions for elderly fall prevention: A systematic literature review. *Applied Ergonomics*, *65*, 570–581. https://doi.org/10.1016/j.apergo.2016.10.013

Donath, L., Rössler, R., & Faude, O. (2016). Effects of Virtual Reality Training (Exergaming) Compared to Alternative Exercise Training and Passive Control on Standing Balance and Functional Mobility in Healthy Community-Dwelling Seniors: A Meta-Analytical Review. *Sports Medicine (Auckland, N.Z.)*, *46*(9), 1293–1309. https://doi.org/10.1007/s40279-016-0485-1

Fissler, P., Küster, O., Schlee, W., & Kolassa, I.-T. (2013). Novelty Interventions to Enhance Broad Cognitive Abilities and Prevent Dementia. In *Progress in Brain Research* (Vol. 207, pp. 403–434). Elsevier. https://doi.org/10.1016/B978-0-444-63327-9.00017-5

Ghai, S., Ghai, I., & Effenberg, A. O. (2017). Effects of dual tasks and dual-task training on postural stability: A systematic review and meta-analysis. *Clinical Interventions in Aging*, *Volume 12*, 557–577. https://doi.org/10.2147/CIA.S125201

Gheysen, F., Poppe, L., DeSmet, A., Swinnen, S., Cardon, G., De Bourdeaudhuij, I., Chastin, S., & Fias, W. (2018). Physical activity to improve cognition in older adults: Can physical activity programs enriched with cognitive challenges enhance the effects? A systematic review and meta-analysis. *International Journal of Behavioral Nutrition and Physical Activity*, *15*(1). https://doi.org/10.1186/s12966-018-0697-x

Howes, S. C., Charles, D. K., Marley, J., Pedlow, K., & McDonough, S. M. (2017). Gaming for Health: Systematic Review and Meta-analysis of the Physical and Cognitive Effects of Active Computer Gaming in Older Adults. *Physical Therapy*, *97*(12), 1122–1137. https://doi.org/10.1093/ptj/pzx088

Joubert, C., & Chainay, H. (2018). Aging brain: The effect of combined cognitive and physical training on cognition as compared to cognitive and physical training alone – a systematic review. *Clinical Interventions in Aging*, *Volume 13*, 1267–1301. https://doi.org/10.2147/CIA.S165399

Kappen, D. L., Mirza-Babaei, P., & Nacke, L. E. (2019). Older Adults' Physical Activity and Exergames: A Systematic Review. *International Journal of Human-Computer Interaction*, *35*(2), 140–167. Scopus. https://doi.org/10.1080/10447318.2018.1441253

Karssemeijer, E. G. A., Aaronson, J. A., Bossers, W. J., Smits, T., Olde Rikkert, M. G. M., & Kessels, R. P. C. (2017). Positive effects of combined cognitive and physical exercise training on cognitive function in older adults with mild cognitive impairment or dementia: A meta-analysis. *Ageing Research Reviews*, *40*, 75–83. https://doi.org/10.1016/j.arr.2017.09.003

Kelly, V. E., Eusterbrock, A. J., & Shumway-Cook, A. (2013). Factors influencing dynamic prioritization during dual-task walking in healthy young adults. *Gait & Posture*, *37*(1), 131–134. https://doi.org/10.1016/j.gaitpost.2012.05.031

Knaepen, K., Goekint, M., Heyman, E. M., & Meeusen, R. (2010). Neuroplasticity – Exercise-Induced Response of Peripheral Brain-Derived Neurotrophic Factor: A

Systematic Review of Experimental Studies in Human Subjects. *Sports Medicine*, *40*(9), 765–801. https://doi.org/10.2165/11534530-000000000-00000

Larsen, L. H., Schou, L., Lund, H. H., & Langberg, H. (2013). The Physical Effect of Exergames in Healthy Elderly-A Systematic Review. *Games for Health Journal*, *2*(4), 205–212. https://doi.org/10.1089/g4h.2013.0036

Lauenroth, A., Ioannidis, A. E., & Teichmann, B. (2016). Influence of combined physical and cognitive training on cognition: A systematic review. *BMC Geriatrics*, *16*(1). https://doi.org/10.1186/s12877-016-0315-1

Laufer, Y., Dar, G., & Kodesh, E. (2014). Does a Wii-based exercise program enhance balance control of independently functioning older adults? A systematic review. *Clinical Interventions in Aging*, *9*, 1803–1813. https://doi.org/10.2147/CIA.S69673

Levin, O., Netz, Y., & Ziv, G. (2017). The beneficial effects of different types of exercise interventions on motor and cognitive functions in older age: A systematic review. *European Review of Aging and Physical Activity*, *14*(1). https://doi.org/10.1186/s11556-017-0189-z

Lipardo, D. S., Aseron, A. M. C., Kwan, M. M., & Tsang, W. W. (2017). Effect of Exercise and Cognitive Training on Falls and Fall-Related Factors in Older Adults With Mild Cognitive Impairment: A Systematic Review. *Archives of Physical Medicine and Rehabilitation*, *98*(10), 2079–2096. https://doi.org/10.1016/j.apmr.2017.04.021

Lord, S. R., & Close, J. C. T. (2018). New horizons in falls prevention. *Age and Ageing*, *47*(4), 492–498. https://doi.org/10.1093/ageing/afy059

Lussier, M., Bugaiska, A., & Bherer, L. (2017). Specific transfer effects following variable priority dual-task training in older adults. *Restorative Neurology and Neuroscience*, *35*(2), 237–250. https://doi.org/10.3233/RNN-150581

Miller, K. J., Adair, B. S., Pearce, A. J., Said, C. M., Ozanne, E., & Morris, M. M. (2014). Effectiveness and feasibility of virtual reality and gaming system use at home by older adults for enabling physical activity to improve health-related domains: A systematic review. *Age and Ageing*, *43*(2), 188–195. https://doi.org/10.1093/ageing/aft194

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & The PRISMA Group. (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Medicine*, *6*(7), e1000097. https://doi.org/10.1371/journal.pmed.1000097

Molina, K. I., Ricci, N. A., de Moraes, S. A., & Perracini, M. R. (2014). Virtual reality using games for improving physical functioning in older adults: A systematic review. *Journal of Neuroengineering and Rehabilitation*, *11*, 156. https://doi.org/10.1186/1743-0003-11-156

Montero-Odasso, M., Verghese, J., Beauchet, O., & Hausdorff, J. M. (2012). Gait and cognition: A complementary approach to understanding brain function and the risk of falling. *Journal of the American Geriatrics Society*, *60*(11), 2127–2136. https://doi.org/10.1111/j.1532-5415.2012.04209.x

Nelson, M., Rejeski, W., Blair, S., Duncan, P., Judge, J., King, A., Macera, C., & Castaneda-Sceppa, C. (2007). Physical Activity and Public Health in Older Adults: Recommendation From the American College of Sports Medicine and the American Heart Association. *Circulation*, *116*(9), 1094–1105. https://doi.org/10.1161/CIRCULATIONAHA.107.185650

Neri, S. G., Cardoso, J. R., Cruz, L., Lima, R. M., de Oliveira, R. J., Iversen, M. D., & Carregaro, R. L. (2017). Do virtual reality games improve mobility skills and balance measurements in community-dwelling older adults? Systematic review and meta-analysis. *Clinical Rehabilitation*, *31*(10), 1292–1304. https://doi.org/10.1177/0269215517694677

Nyman, S. R., & Victor, C. R. (2012). Older people's participation in and engagement with falls prevention interventions in community settings: An augment to the Cochrane systematic review. *Age and Ageing*, *41*(1), 16–23. https://doi.org/10.1093/ageing/afr103

Oswald, W. D., Gunzelmann, T., Rupprecht, R., & Hagen, B. (2006). Differential effects of single versus combined cognitive and physical training with older adults: The SimA study in a 5-year perspective. *European Journal of Ageing*, *3*(4), 179–192. https://doi.org/10.1007/s10433-006-0035-z

Perrochon, A., Borel, B., Istrate, D., Compagnat, M., & Daviet, J.-C. (2019). Exercise-based games interventions at home in individuals with a neurological disease: A systematic review and meta-analysis. *Annals of Physical and Rehabilitation Medicine*, S1877065719300600. https://doi.org/10.1016/j.rehab.2019.04.004

Pieper, D., Antoine, S.-L., Mathes, T., Neugebauer, E. A. M., & Eikermann, M. (2014). Systematic review finds overlapping reviews were not mentioned in every other overview. *Journal of Clinical Epidemiology*, *67*(4), 368–375. https://doi.org/10.1016/j.jclinepi.2013.11.007

Pietrzak, E., Cotea, C., & Pullman, S. (2014). Using commercial video games for falls prevention in older adults: The way for the future? *Journal of Geriatric Physical Therapy (2001)*, *37*(4), 166–177. https://doi.org/10.1519/JPT.0b013e3182abe76e

Plummer, P., Zukowski, L. A., Giuliani, C., Hall, A. M., & Zurakowski, D. (2015). Effects of Physical Exercise Interventions on Gait-Related Dual-Task Interference in Older Adults: A Systematic Review and Meta-Analysis. *Gerontology*, *62*(1), 94–117. https://doi.org/10.1159/000371577

Pollock, M, Fernandes, R., Becker, L., Pieper, D., & Hartling, L. (2018). Cochrane Handbook for Systematic Reviews of Interventions. In *Chapter V: Overviews of Reviews* (Cochrane Handbook for Systematic Reviews of Interventions). Cochrane.

Pollock, Michelle, Fernandes, R. M., Becker, L. A., Featherstone, R., & Hartling, L. (2016). What guidance is available for researchers conducting overviews of reviews of healthcare interventions? A scoping review and qualitative metasummary. *Systematic Reviews*, *5*(1), 190. https://doi.org/10.1186/s13643-016-0367-5

Reis, E., Postolache, G., Teixeira, L., Arriaga, P., Lima, M. L., & Postolache, O. (2019). Exergames for motor rehabilitation in older adults: An umbrella review. *Physical Therapy Reviews*, 1–16. https://doi.org/10.1080/10833196.2019.1639012

Rodrigues, E., Valderramas, S., Rossetin, L., & Gomes, A. R. (2014). Effects of video game training on the musculoskeletal function of older adults: A systematic review and meta-analysis. *Topics in Geriatric Rehabilitation*, *30*(4), 238–245. Scopus. https://doi.org/10.1097/TGR.0000000000000040

Schaefer, S., & Schumacher, V. (2011). The interplay between cognitive and motor functioning in healthy older adults: Findings from dual-task studies and suggestions for intervention. *Gerontology*, *57*(3), 239–246. https://doi.org/10.1159/000322197

Schardt, C., Adams, M. B., Owens, T., Keitz, S., & Fontelo, P. (2007). Utilization of the PICO framework to improve searching PubMed for clinical questions. *BMC Medical Informatics and Decision Making*, *7*, 16. https://doi.org/10.1186/1472-6947-7-16

Schoene, D., Valenzuela, T., Lord, S. R., & de Bruin, E. D. (2014). The effect of interactive cognitive-motor training in reducing fall risk in older people: A systematic review. *BMC Geriatrics*, *14*(1). https://doi.org/10.1186/1471-2318-14-107

Shea, B. J., Reeves, B. C., Wells, G., Thuku, M., Hamel, C., Moran, J., Moher, D., Tugwell, P., Welch, V., Kristjansson, E., & Henry, D. A. (2017). AMSTAR 2: A critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. *BMJ (Clinical Research Ed.)*, *358*, j4008. https://doi.org/10.1136/bmj.j4008

Skjæret, N., Nawaz, A., Morat, T., Schoene, D., Helbostad, J. L., & Vereijken, B. (2016). Exercise and rehabilitation delivered through exergames in older adults: An integrative review of technologies, safety and efficacy. *International Journal of Medical Informatics*, *85*(1), 1–16. https://doi.org/10.1016/j.ijmedinf.2015.10.008

Stojan, R., & Voelcker-Rehage, C. (2019). A Systematic Review on the Cognitive Benefits and Neurophysiological Correlates of Exergaming in Healthy Older Adults. *Journal of Clinical Medicine*, *8*(5). https://doi.org/10.3390/jcm8050734

Tait, J. L., Duckham, R. L., Milte, C. M., Main, L. C., & Daly, R. M. (2017). Influence of Sequential vs. Simultaneous Dual-Task Exercise Training on Cognitive Function in Older Adults. *Frontiers in Aging Neuroscience*, *9*. https://doi.org/10.3389/fnagi.2017.00368

Taylor, L. M., Kerse, N., Frakking, T., & Maddison, R. (2018). Active Video Games for Improving Physical Performance Measures in Older People: A Meta-analysis. *Journal of Geriatric Physical Therapy (2001)*, *41*(2), 108–123. https://doi.org/10.1519/JPT.0000000000000078

Vázquez, F. L., Otero, P., García-Casal, J. A., Blanco, V., Torres, Á. J., & Arrojo, M. (2018). Efficacy of video game-based interventions for active aging. A systematic literature review and meta-analysis. *PLOS ONE*, *13*(12), e0208192. https://doi.org/10.1371/journal.pone.0208192

Wang, X., Pi, Y., Chen, P., Liu, Y., Wang, R., & Chan, C. (2015). Cognitive motor interference for preventing falls in older adults: A systematic review and meta-analysis of randomised controlled trials. *Age and Ageing*, *44*(2), 205–212. https://doi.org/10.1093/ageing/afu175

Wollesen, B., & Voelcker-Rehage, C. (2014). Training effects on motor–cognitive dual-task performance in older adults: A systematic review. *European Review of Aging and Physical Activity*, *11*(1), 5–24. https://doi.org/10.1007/s11556-013-0122-z

Yogev-Seligmann, G., Hausdorff, J. M., & Giladi, N. (2008). The role of executive function and attention in gait. *Movement Disorders: Official Journal of the Movement Disorder Society*, *23*(3), 329–342; quiz 472. https://doi.org/10.1002/mds.21720

Yogev-Seligmann, G., Rotem-Galili, Y., Mirelman, A., Dickstein, R., Giladi, N., & Hausdorff, J. M. (2010). How does explicit prioritization alter walking during dual-task performance? Effects of age and sex on gait speed and variability. *Physical Therapy*, *90*(2), 177–186. https://doi.org/10.2522/ptj.20090043

Zhu, X., Yin, S., Lang, M., He, R., & Li, J. (2016). The more the better? A meta-analysis on effects of combined cognitive and physical intervention on cognition in healthy older adults. *Ageing Research Reviews*, *31*, 67–79. https://doi.org/10.1016/j.arr.2016.07.003

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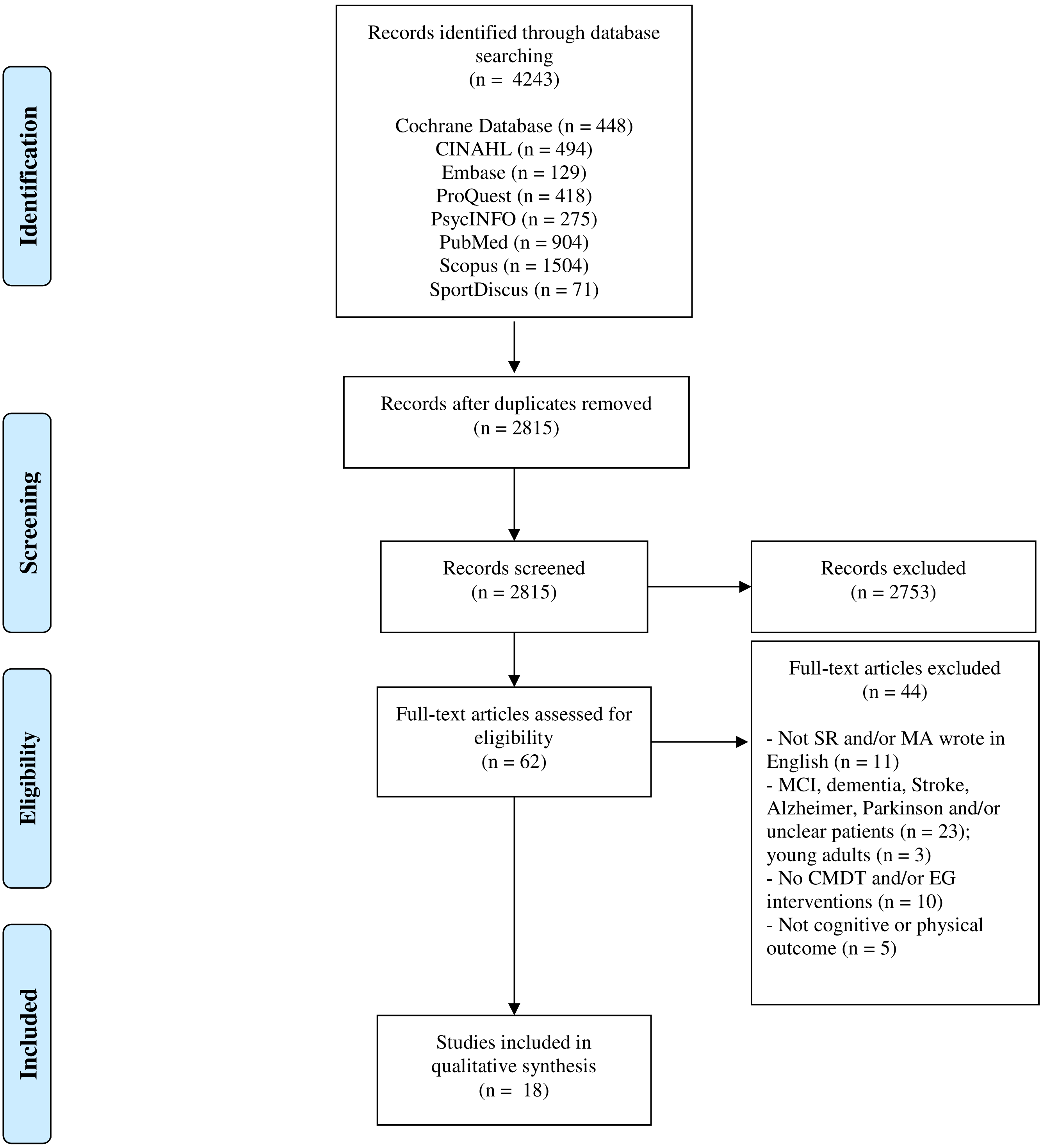

Figure A : selection of systematic reviews
SR : systematic review; MA : meta-analysis ; CMDT : cognitive-motor dual-task; EG : exergame; MCI : mild cognitive impairment

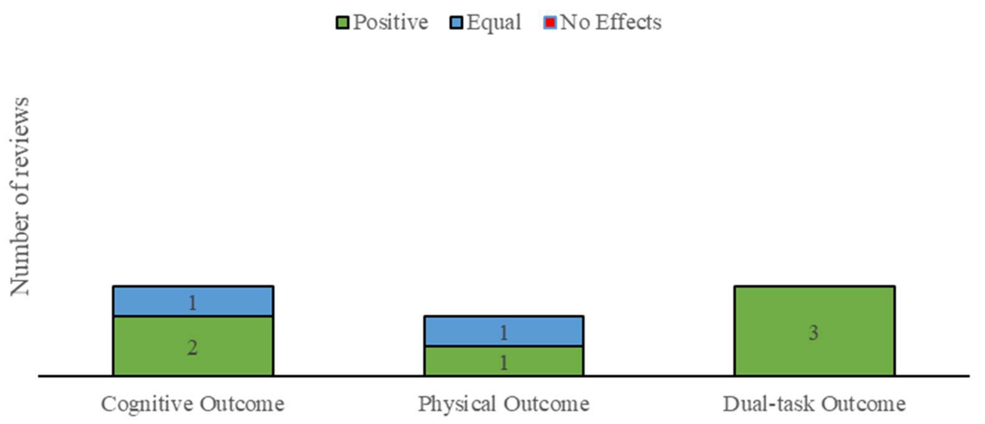

Figure B.1.

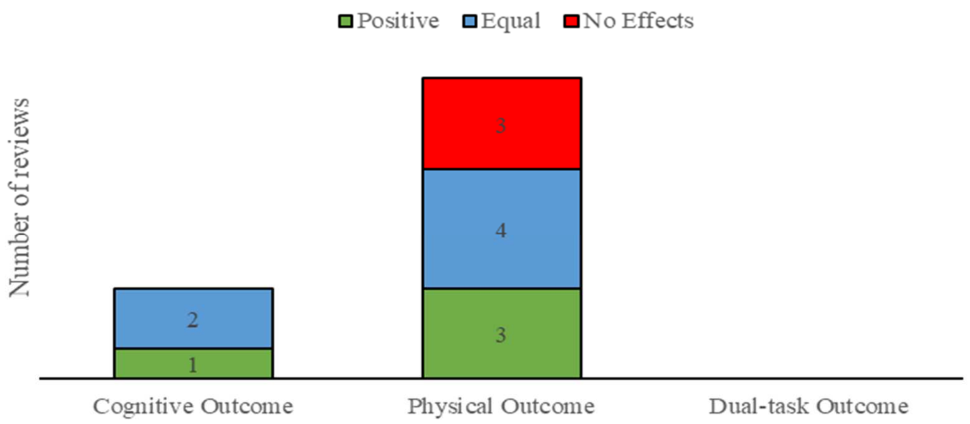

Figure B.2.

Figure B : effects of cognitive-motor dual-task (CMDT) (1) and exergame (EG) (2) interventions on cognitive, physical or dual-task outcomes.

Review First author, year Country	**Objectives** 1) Primary 2) Secondary	**Included literature :** Review design (N) Primary studies design (N)	**Population :** N (Exp / Ctrl) Age (range or mean) Characteristics (N)	**Interventions** Experimental or control group, content (N)	**Modalities :** Seq / Sim Grp / Ind Center / home Duration min Duration max	**Outcomes** Type, functions assessed	**Conclusions** 1) Primary objective 2) Secondary objective	**RoB** Scale , score or criteria (mean ± SD) or [range] Appreciation
COGNITIVE-MOTOR DUAL-TASK TRAINING								
Cognitive outcome								
Joubert, 2018 France	1) Effects of CMDT compared with cognitive or physical STT on cognition 2) Assess retention and transfer	SR (52) RCT (36), NRSI (16)	20512 (n.r.) n.r. HE (52)	**Exp** : CMDT (~~Wii, Kinect, cybercycling, treadmill,~~ combined cognitive & physical training) (7), EG (Wii) (1) **Ctrl** : NI (n.r.) and/or active : physical STT (resistance, aerobic, stretching, balance) (10), cognitive STT (speed processing, attention, memory, visuospatial abilities, task switching) (31)	Sim (2), Seq (6) n.r. n.r. 60 min, 1x 90min, 1x/w, 30w	**Cognitive** : attention, PS, memory, EF, visuospatial performance	1) Improving cognition, CMDT are superior to cognitive and physical STT 2) Retention (4) and transfer (1) were unclear	PEDro (/10) [4-10], for DT training [5-11] n.r.
Zhu, 2016 China	1) Effects of CMDT compared with cognitive or physical STT on cognition	SR (20) - MA (20) RCT (14), NRSI (6)	2667 (1667 - 1000) [65 - 82] HE (20)	**Exp** : EG (3), CMDT (20), combining a cognitive task (multidomain (11), single domain (4)) with a physical task (multicomponent exercises (12), aerobic (6), strength and balance (1)) **Ctrl** : education (3), NI (11), and/or STT (3)	Sim (6), Seq (14) Grp (10), Ind (3), mixed (4) n.r. 30 min, 3x/w, 6w 10-60min, 3-11x/w, 96 w	**Cognitive** : global cognition, memory, EF, attention, PS, visuospatial performance	1) Improving cognition, CMDT are superior to NI, TI and physical STT; equivalent to cognitive STT	Modified PEDro (/9) 6,3 ± 1,3 [2-9] 7 low, 13 high risk
Physical outcome								
Wang, 2015 China	1) Effects of CMDT compared with STT or NI on falls	SR (30) - MA (30) RCT (10), NRSI (20)	1206 (n.r.) n.r. HE (30)	**Exp** : CMDT (n.r.) **Ctrl** : NI or STT (n.r.)	n.r. n.r. n.r. n.r.	**Physical** : gait, balance, falls, reaction time	1) Improving gait, balance and preventing falls, CMDT are superior to STT and NI 2) No serious adverse events	PEDro (/10) 5.4 ± 1.4 [3-8] 1 low, 21 moderate, 8 high risk
Cognitive and Physical outcome								

Levin, 2017 Israel	1) Effects of CMDT on cognitive and motor functions	SR (19) RCT (6), NRSI (13)	1226 (843 / 383) [66 - 82] HE (19)	**Exp** : STT (6), combined exercise training (aerobic, balance,resistance) (4), CMDT (10) (aerobic, balance, and resistance training with flexibility and memory tasks), **Ctrl** : NI and/or active STT (n.r.)	Sim (6), Seq (3) n.r. n.r. 7 sets, 8 rep, 2x/w, 6w 60min, 2x/w, 24w	**Physical** : mobility, gait, balance, strength, psychomotor tasks, aerobic fitness **Cognitive** : PS, EF, attention, DT cost	1) Improving physical functions, CMDT are equivalent to MMDTT; improving cognitive functions, CMDT are superior to MMDTT (psychomotor speed, processing speed, attention and DT cost)	Jadad (/5) [1-4] n.r.
Dual-task outcome								
Plummer, 2015 USA	1) Effects of CMDT compared with STT on DT gait performance	SR (21) - MA (14) RCT (15), NRSI (6)	911 (n.r.) [71 - 91] HE (13), BI, fall (5), frail (2)	**Exp** : MMDTT (4) and CMDT (9), combining a physical task (walking, balance, coordination, stretching, tai-chi, step, aerobic, strength) with a physical or a cognitive task (comprehension, arithmetic, verbal fluency, working memory) **Ctrl** : education (1), NI (11), or active : STT or FPP (9)	Sim (9), Seq (1) Grp (12), Ind (7), mixed (2) n.r. 45 min, 3x/w, 4w 60min, 1x/w, 25w	**Physical :** Gait under DT conditions	1) Improving gait speed, CMDT are superior to NI and TI, and equivalent to STT	Downs & Black (/25) 16,8 [12-21] 4 high, 13 good, 4 low quality
Wollesen, 2014 Germany	1) Effects of CMDT compared with STT on DT performances	SR (13) RCT (6), NRSI (7)	387 (n.r.) n.r. HE (11), fall (2)	**Exp** : CMDT (9), combining a physical (balance, strength, walking) and a cognitive task (memory, verbal, visuospatial, music), VR (2) **Ctrl** : STT (balance, walking) (5)	n.r. n.r. n.r. 60min, 3x 60min, 1x/w, 48w	**Physical** : postural control, mobility, gait **Cognitive** : PS, visuospatial performance, EF	1) Improving DT standing performance, CMDT are superior to STT; improving DT walking performance, CMDT are equivalent to STT	Modified Van Tulder (/12) [3-11] 5 High quality
Agmon, 2014 Israel	1) Effects of different interventions on DT postural control	SR (22) RCT (16), NRSI (6)	730 (387 / 343) ≥ 60 HE (6), fall (7)	**Exp** : CMDT (13), combining a physical (walking, balance, gait, agility) and a cognitive task (calculation, verbal and working memory), STT (postural) (9) **Ctrl** : education (4), NI (3) and/or STT (6)	n.r. Grp (14), Ind (8) n.r. 45min, 1x/w, 4w 60min, 1x/w, 25w	**Physical** : postural control, balance and gait under DT	1) Improving DT postural control, CMDT are superior to STT	Portney and Watkins (n.r.) [1-4] n.r.
EXERGAME								
Cognitive outcome								

Stojan, 2019 Germany	1) Effects of EG on cognitive domains (neurophysiological outcomes mostly)	SR (15) RCT (12), NRSI (3)	750 (n.r.) [60 - 85] HE (15)	**Exp** : Kinect (4), VR (3), dance videogame (5) including DDR (2), Cybercycle (2), Cyberstep (2), Wii (1) **Ctrl** : NI (n.r.) and/or active STT (n.r.)	Sim (15) n.r. n.r. 30min, 2x/w, 6w 60min, 2x/w, 26w	**Cognitive** : memory, EF, PS, visuospatial performance	1) Improving cognitive and brain functions, EG are effective (small and strongly varying positive effects); improving EF, EG are similar or slightly superior to TI	CCRT n.r. 3 High, 4 moderate, 6 low, 2 n.r.
Physical outcome								
Taylor, 2018 New Zealand	1) Effects of EG on physical functions 2) Assess the safety, game appeal, and usability	SR (18) - MA (10) RCT (18)	765 (n.r.) n.r. HE (13), BI or RoF (3), unclear (2)	**Exp** : Wii (11), pressure-sensitive systems (5), Kinect (1), VR (1) **Ctrl** : placebo (2), NI (9) and/or FPP (16)	Sim (18) Grp (2), Ind (16) Home (1), center (17) Mean : 40 min, 2-3x/w, 8w	**Physical** : mobility, balance	1) Improving balance and mobility, EG are superior to NI and TI 2) Safe when supervised, good adherence, enjoyed	CCRT n.r. 4 low, 14 high or unclear
Choi, 2017 South Korea	1) Effects of EG on fall	SR (25) RCT (6), NRSI (19)	752 (525 / 227) >60 HE (19), BI (6)	**Exp** : Wii (14), Kinect (5), SensBalance Fitness Board (2), DDR (1), others (3) **Ctrl** : NI (n.r.) and/or active : STT or FPP (n.r.)	Sim (25) n.r. Home (11), Center (14) 30min, 3x/w, 3w 45min, 3x/w, 15w	**Physical** : strength, RoF, balance, gait, mobility **Cognitive** : cognitive functions (not specified)	1) Improving balance, EG are superior to NI, and equivalent to TI	n.r. n.r. n.r.
Neri, 2017 Brazil	1) Effects of EG compared with NI or TI on fall	SR (28) - MA (6) RCT (28)	1121 (n.r.) n.r. HE (28), fall (2), prefrail (1)	**Exp** : Wii (15), VR (4), Cyberstep (3), dance videogame (2), Kinect (1), others (4) **Ctrl** : NI (12) or FPP (16)	Sim (28) n.r. n.r. 40 min, 3x/w, 2w 60 min, 1x/w, 20w	**Physical :** balance, strength, reaction time, mobility, RoF	1) Improving mobility and balance, EG are superior to NI; improving balance and RoF, EG are superior to TI	CCRT n.r. n.r.
Donath, 2016 Switzerland	1) Effects of EG compared with TI or NI on balance	SR (18) - MA (18) RCT (15), NRSI (3)	619 (n.r.) 76 ± 5 HE (15), fall (3)	**Exp** : Wii (12), VR (5), DDR (1) **Ctrl** : NI (13), and/or active : STT or FPP (9)	Sim (18) n.r. n.r. <45min, 2x/w, 3w 60min, 1x/w, 20w	**Physical** : balance, mobility, postural control	1) Improving mobility and balance, EG are superior to NI; improving standing balance and functional mobility, EG are inferior to TI	PEDro (/10) [4-8] n.r.
Molina, 2014 Brazil	1) Effects of EG on physical functions	SR (13) RCT (10), NRSI (3)	487 (n.r.) n.r. HE (4)	**Exp** : Wii (8), dance video game (2), balance or step training (1), computer games (2). EG only (7) or EG + physical activity (6) **Ctrl** : placebo (1), NI (6) and/or active : STT or FPP (9)	Sim (13) Grp (2), Ind (6), unclear (5) Additional home (1) 30min, 2x/w, 3w 30min, 2x/w, 12w	**Physical** : mobility, balance, RoF, strength, postural control, reaction time, gait	1) EG did not increase physical functions 2) Positive motivational aspect with EG	PEDro (/10) 5.6 ± 1.3 [4-8] n.r.

Rodrigues, 2014 Brazil	1) Effects of EG on musculoskeletal functions	SR (16) - MA (4) RCT (14), NRSI (2)	532 (268 / 264) n.r. HE (16)	**Exp** : Wii (10), Dance video game (2), VR (1), others (3) **Ctrl** : NI (10), and/or physical activity (7)	Sim (16) n.r. n.r. 15min, 2x/w, 3w ? min, 1x/w, 20w	**Physical** : balance, mobility, strength, falls efficacy scale, gait, fear of falling	1) EG did not increase functional mobility nor the fear of falls	Jadad (/5): [1-3] 9 low, 7 high
Laufer, 2014 Israel	1) Effects of EG (Wii) compared with TI or NI on balance control	SR (7) RCT (7)	285 (126 / 159) [61 - 86] HE (7)	**Exp** : Wii Mote (1), Wii Balance Board (7) **Ctrl** : placebo (1), NI (3) and/or active : FPP (5)	Sim (7) Grp (1), Ind (6) n.r. 40min, 2x/w, 6w 60 min, 1x/w, 20w	**Physical** : standing/walking balance, postural sway, fitness, strength, falls	1) Improving balance, EG are superior to NI and equivalent to TI; and feasible	PEDro (/10) 5.6 ± 0.8 [5-7] n.r.
Larsen, 2013 Denmark	1) Effects of EG on physical outcomes	SR (7) RCT (7)	311 (n.r.) [73 - 86] HE (7)	**Exp :** Wii (4), DDR (1), Cybercycle (1), other (1) **Ctrl :** NI (4) and/or active : FPP (5), tai-chi (1)	Sim (7) n.r. n.r. 3w 20w	**Physical** : balance, mobility, strength	1) Improving physical functions, EG are superior to NI, and equivalent to TI 2) Additional cognitive effect of EG (assessed in 1 study)	CCRT n.r. n.r.
Cognitive and Physical outcome								
Bleakley, 2015 United Kingdom	1) Effects of EG on physical and cognitive functions 2) Assess the compliance, enjoyment and adverse events	SR (12) RCT (5), NRSI (7)	455 (n.r.) >65 HE (9), fall (1), BI (1)	**Exp** : VR (4), Wii (4), computerized balance training (3), dance mat (1) **Ctrl** : education (1), NI (2) and/or active : STT or FPP (5)	Sim (12) n.r. n.r. 20 min, 2x/w, 4w 90 min, 2x/w, 12w	**Physical** : postural control, balance strength, falls **Cognitive** : global cognition, EF, memory, attention, PS	1) Improving physical and cognitive functions, EG are effective 2) EG are safe; the optimal dose, enjoyment and adherence remains unclear	CCRT n.r. n.r.
Schoene, 2014 Netherlands	1) Effects of EG# compared with TI on falls and RoF	SR (37) n.r.	1066 (n.r.) n.r. HE (21), functional impairment (16), fall or BI (6)	**Exp** : Wii Balance Board (16), WiiMote (10), pressure-sensitive platforms (7), force plates with VR (3), tillable platforms (2), Kinect (1), EyeToy (1), Fovea (1), walks film projected onto a screen (1), others (2) **Ctrl** : NI (9) and/or active (9)	n.r. n.r. Center (34), home (2), mixed (1) 30min, 3x/w, 3w 60min, 2x/w, 12w	**Physical** : step, balance, mobility, falls, balance, postural control, strength **Cognitive** : attention, EF, global cognition	1) Improving physical and cognitive fall risk factors, EG# are equivalent to TI; effects on falls remains unclear	Modified Downs and Black (/27) 16.8 ± 4.5 [5, 24] n.r.

Table A : characteristics of included systematic reviews

BI : balance impairment; CCRT : Cochrane Collaborations RoB Tool; CMDT : cognitive-motor dual-task; Ctrl : control group; DDR : dance-dance revolution; DT : dual-task; EF : executive functions; EG : exergame ; Exp : experimental group; FPP: fall prevention programs; Grp : group; HE : healthy elderly; Ind : individual; MA : meta-analysis; min : minutes; MMDTT: motor-motor dual-task training; NI : no intervention; NRSI : non-randomized studie of interventions ; n.r. : not reported; PEDro : Physiotherapy Evidence Database; PS : processing speed; QOL : quality of life; RCT : randomized controlled trial; RoB : risk of bias; RoF : risk of fall; SR : systematic review; Seq : sequential; Sim : simultaneous; STT : single-task training; VR : virtual reality; w : week; # CMDT,requalified as EG.

Systematic Review	AMSTAR-2 Criteria																		Rating (/16)	Overall confidence in the results of the review
	Use PICO	Method	Inclusion	Search strategy	Selection x2	Extraction x2	Exclusions	Description	RoB - RCT	RoB - N-RCT	Funding	MA : Method	MA : Method	MA : RoB	RoB discuted	Heterogeneity	MA : RoB	COI / funding		
	1	2*	3	4*	5	6	7*	8	9-1*	9-2*	10	11-1*	11-2*	12	13*	14	15*	16		
Larsen, 2013	Y	P	N	N	Y	N	N	P	Y	n.a.	N	n.a.	n.a.	n.a.	N	Y	n.a.	Y	5	Critically low
Laufer, 2014	Y	N	N	Y	Y	Y	N	P	P	n.a.	N	n.a.	n.a.	n.a.	N	N	n.a.	Y	5	Critically low
Rodrigues, 2014	Y	P	N	P	Y	Y	N	N	P	N	N	Y	N	N	Y	Y	N	Y	7	Critically low
Agmon, 2014	N	P	N	P	Y	Y	N	Y	N	N	N	n.a.	n.a.	n.a.	N	N	n.a.	Y	4	Critically low
Wollesen, 2014	Y	P	Y	P	N	N	Y	Y	P	Y	N	n.a.	n.a.	n.a.	N	Y	n.a.	Y	7	Low
Molina, 2014	Y	N	N	P	Y	N	N	P	P	n.a.	N	n.a.	n.a.	n.a.	Y	Y	n.a.	Y	5	Critically low
Schoene, 2014	Y	N	N	P	Y	N	N	N	P	Y	N	n.a.	n.a.	n.a.	Y	Y	n.a.	Y	5	Critically low
Plummer, 2015	Y	Y	N	N	Y	Y	Y	P	Y	Y	N	Y	n.a.	Y	N	Y	Y	Y	12	Low
Wang, 2015	Y	Y	N	P	Y	Y	N	N	P	n.a.	N	Y	n.a.	N	N	Y	Y	N	9	Critically low
Bleakley, 2015	N	P	N	N	Y	Y	N	P	N	N	N	n.a.	n.a.	n.a.	N	Y	n.a.	Y	4	Critically low
Donath, 2016	Y	P	N	P	Y	Y	N	P	P	n.a.	N	N	N	Y	Y	Y	Y	Y	8	Critically low
Zhu, 2016	Y	Y	N	P	Y	Y	N	P	P	P	N	Y	N	N	N	N	Y	Y	8	Critically low
Neri, 2017	Y	Y	N	P	Y	Y	N	Y	Y	n.a.	N	Y	n.a.	Y	Y	Y	N	Y	11	Critically low
Choi, 2017	Y	N	N	P	Y	N	N	P	N	N	N	n.a.	n.a.	n.a.	N	N	n.a.	N	2	Critically low
Levin, 2017	Y	P	N	N	Y	N	Y	N	P	N	N	n.a.	n.a.	n.a.	N	N	n.a.	Y	8	Critically low
Taylor, 2016	Y	P	N	N	Y	N	N	P	Y	n.a.	N	Y	n.a.	N	N	Y	N	Y	6	Critically low
Joubert, 2018	Y	P	N	N	N	N	N	P	Y	Y	N	n.a.	n.a.	n.a.	N	Y	n.a.	Y	5	Critically low
Stojan, 2019	Y	N	N	P	Y	Y	N	P	Y	n.a.	N	n.a.	n.a.	n.a.	N	Y	n.a.	Y	6	Critically low
% of "No"	11	28	94	33	11	44	83	22	17	22	100	6	17	22	72	28	17	11	Mean score = 5,8	

Table B : methodological quality of systematic reviews

*: AMSTAR 2 critical domains; Y: Yes; P: Partially yes; N: No; n.a.: not applicable

Rating overall confidence in the results of the review

High: no or one non-critical weakness. The systematic review provides an accurate and comprehensive summary of the results of the available studies that address the question of interest

Moderate: more than one non-critical weakness*. The systematic review has more than one weakness but no critical flaws. It may provide an accurate summary of the results of the available studies that were included in the review

Low: one critical flaw with or without non-critical weaknesses. The review has a critical flaw and may not provide an accurate and comprehensive summary of the available studies that address the question of interest

Critically low: more than one critical flaw with or without non-critical weaknesses. The review has more than one critical flaw and should not be relied on to provide an accurate and comprehensive summary of the available studies