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Neural Control of Movement

Effects of relative frequency knowledge results in acquisition of motor skills in people with Down Syndrome

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Abstract - Down Syndrome (DS) is a known genetic condition associated with intellectual disability, which makes it necessary to have different conditions of manipulation of frequency of knowledge of results (KR) for the acquisition of motor skills. The present study aimed to investigate the effects of relative frequency of KR on the acquisition of motor skills of individuals with DS. Twenty subjects performed a throwing task towards a target positioned on the ground. The study consisted of acquisition phase and testing. Ten minutes after the acquisition phase, the transfer test was performed containing ten attempts of the same pitch with different distance from the acquisition phase and no KR presentation. Two groups were organized, DSG100 with DS individuals and 100% KR frequency and DSG50 with DS individuals and 50% KR frequency. The results showed that DSG50 performed better than the DSG100 indicating that as in individuals who do not have DS the greater amount of information seems to be worse for motor skills performance.

Keywords: Down syndrome, intellectual disability, motor learning, feedback.

Introduction

Down syndrome (DS) is the most common genetic cause of intellectual disability (ID), with an incidence of around 1 in 650-1000 live births worldwide[1]. DS is a developmental disorder caused by the triplication of human chromosome 21 (HSA21)[2], and results from an extra full or partial copy of (HSA21) in a person's karyotype[3], being the main genetic cause of mental retardation in the human population[4], and is also related to several psychosocial limitations and comorbidities[5], of which the most prominent are neonatal hypotonia, delayed development, and premature aging[6], short stature, muscle hypotonia and ligament laxity among others[7], congenital heart disease, endocrine, sensory and orthopedic, Alzheimer's disease, and high rates of early mortality are common among people with DS[8], high obesity rates, very low fitness, functional limitations and a set of other secondary conditions[9], behavioural problems, also social, environmental and familial factors that might be influential[10].

The neuropathological consequences of trisomy 21 begin during fetal development with decreased cell division and increased apoptosis that together lead to hypoplasia of the hippocampus, neocortex and cerebellum[11]. After birth, brain morphology continues to diverge compared with typically developing individuals[12]. In particular, cortical layer thickness, dendritic branching, synapse formation, brain size and overall brain weight are all reduced[13]. Delayed and altered myelination of white matter tracts has also been reported[14], as well as specific abnormalities are present in the prefrontal cortex[15]. By adulthood, brains of individuals with DS show a 24% reduction in size, with a decrease in volume of the cerebellum (-33%), hippocampus (-27%) and frontal cortex (-17%)[2]. Cognitive domains that are particularly impaired in individuals with DS include language (especially expressive language), memory, executive function, and motor coordination[1].

For Winnick[16], the intellectual capacity of the individual with DS has severe limitations because they stay longer in the sensorimotor stage and in the adult phase because they are unable to go beyond the level of concrete operations. Regarding the motor domain, individuals with DS have a delay in the acquisition of basic motor milestones, such as reaching for objects, crawling, standing independently, walking, etc. They also lag behind babies without Down syndrome in fine motor skills that involve hand manipulation of objects, such as drawing, writing, tying shoe laces and playing musical instruments[17], indicating that these appear in a longer time compared to individuals with normal development[18]. This characteristic seems to influence the motor skills acquisition process. It is assumed that individuals with DS form more unstable reference structures, compromising both decision making and the ranking of the elements. This condition may be related to the difficulty of forming action programs and the difficulty of establishing temporal relationships between the components of a task[19]. Regarding the motor domain, individuals with DS have a delay in the acquisition of basic motor milestones, such as reaching for objects, crawling, standing independently, walking, etc. They also lag behind babies without Down syndrome in fine motor skills that involve hand manipulation of objects, such as drawing, writing, tying shoe laces and playing musical instruments[17], indicating that these appear in a longer time compared to individuals with normal development[18]. It is assumed that individuals with DS form more unstable reference structures, compromising both decision making and the ranking of the elements. This condition may be related to the difficulty of forming action programs and the difficulty of establishing temporal relationships between the components of a task[19]. This characteristic seems to influence the motor skills acquisition process.

KR, a subcategory of extrinsic feedback, refers to terminal information about the goal achieved in the environment. One of his most studied manipulations is frequency[20]. This manipulation consists of the relationship between the amount of information about the motor skills result and the amount of practice, characterizing it as an important factor in the motor learning acquisition process[21-23]. This frequency when referring to the percentage of attempts in which the individual is receiving KR is called the relative frequency of KR[21]. The KR has been emphasized as an important variable in the learning process, and may be a factor that influences the motor learning of individuals with cognitive impairment, because this variable can be characterized by reference information for the formation and correction of a structure responsible for the acquisition of motor skills[24]. With regard to individuals without cognitive impairment, the initial view regarding the provision of CR determined that the more frequent its presentation, the better the learning would be, thus discarding the possibility of relative frequencies below 100%. These types of arrangements would present attempts without KR that would not be important for the acquisition of motor skills[25-28]. However, lower amounts of KR have been used and showed better results in retention and transfer tests[20].

Relative frequencies lower than 100% (reduced frequencies) would have the role of decreasing the dependence of the feedback allowing the use of intrinsic feedback as information responsible for the elaboration of an error detection and correction mechanism[21]. The results of studies on reduced relative frequency with individuals without cognitive impairment have shown better performances than relative frequencies close to 100%[29-32]. It should be understood that the learner needs extrinsic information to complement intrinsic feedback and thus detect and correct possible errors[33]. Thus, groups receiving high frequency KR direct their performance towards the goal presenting better results than groups with lower frequencies only in the acquisition phase due to the presence of large amounts of KR. However, the use of trials without KR strengthens the use of intrinsic feedback providing better learning as can be seen by the good performance of these groups in the test condition. These findings are confirmed in the studies by Lee, White and Carnahan[31] and Winsten and Schmidt[34]. The study by Sparrow and Summers[32] with a positioning task showed that in the immediate retention test the group with 100% KR showed better results reversing this situation in the delayed retention test. These results confirm Lai and Shea[30] findings that lower KR frequencies lead to better retention performances. Still, Ishikura[29], investigating the reduction of the frequency of KR in the golf putt in divided thirty-four individuals into two groups with relative frequency of 100% and 33%, respectively. The design was composed of acquisition phase and immediate retention test and delayed retention. The results suggested that reducing the frequency of KR was effective for golf putt learning. Confirming these findings, the study by Oliveira et al.[35] using the bocce ball throw with two different levels of complexity, divided 120 children into four different frequencies of 25%, 50%, 75% and 100% KR. The group with 25% KR frequency presented better result for the reduction of the error, besides a higher level of consistency than the other groups.

From the previous assumptions it is understood that higher relative frequencies of KR lead to worse performance on learning tests, while lower relative frequencies are better for learning motor skills. However, the present findings correspond to samples without any form of cognitive impairment. The study by Hodges et al.[36] using a throwing task with individuals with DS presents different conclusions. The results showed that individuals with DS are dependent on visual KR and process information more slowly when compared to individuals without the syndrome. The findings by Byde and Mcclenaghan[37] corroborate the KR dependence of the DS patient, but their results are inconclusive in the acquisition of a coincident timing motor skill.

In an attempt to understand the motor learning process, some studies have tried to analyze the behavior of different variables in the acquisition of motor skills with individuals with DS, an example being the study by Gimenez et al.[19] who highlight Down Syndrome patients have needed more practice to stabilize their performance when compared to individuals without DS. However, studies that used feedback such as Hansen et al.[38] and Hodges et al.[36] stated that individuals with Down syndrome are more dependent on proprioceptive feedback than feedback visual, results similar to individuals who have no cognitive impairment. The study by LATASH et al.[17] and Chiviacowsky et al.[39], suggested that individuals with DS have a greater difficulty in processing information, highlighting a greater need for extrinsic feedback as a result of the discrepancy in the analysis performed by subjects with DS, through internal sources, such as exteroceptive or proprioceptive sensory organs.

Thus, when considering individuals with DS, whose main characteristics are delayed motor development and difficulty in intellectual operations, higher relative frequencies, which are characterized by higher information rates, could be better for the motor learning process to form more stable reference structures which perhaps would provide better performance. From this premise, the objective of the present study was to verify the effects of the relative frequency of knowledge of results on the acquisition of motor skills with individuals with DS.

Material and method

Sample

The study included 20 individuals with DS (12 women and 8 men), volunteers of both sexes, aged between 18 and 33 years (23.6 + 2.5), inexperienced in the task. The study was approved by the Local Ethical Committee, and all subjects signed an informed consent form prior to the first test.

Instrument and task

A circular target 2 m in diameter and 10 circumscribed circles of radius 10 cm, staggered and punctuated was used. The center of the target was assigned a value of 100 points and subsequent areas decreased by 10 points to the outermost circle which had a value of 10 points. The target was made of paper and affixed to the ground, with its center at a distance of 2 m from a cloth curtain, which was 1.40 m high by 2 m wide. This curtain was placed in such a way as to eliminate the subjects' visual information about the result of the launch. The target was further divided into four parts by two X-shaped lines, providing the direction of the throw (long-short and right-left), see Figure 1.

We used circular cloth bags, containing beans and weighing 100 g each. The task used was to throw a bean bag over the shoulder towards the center of the target containing 30 attempts in the acquisition phase and 10 trials in the transfer test. The task used was the same as the study by Chiviacowsky et al.[40] and Chiviacowsky et al.[41].

Experimental design

The 20 individuals were randomized into two groups (n = 10, 6 women and 4 men), DSG100 with individuals with DS and frequency of 100% KR and DSG50 with individuals with DS and frequency of 50% KR. The experiment presented phase of acquisition and transfer test being the number of attempts and the distance determined by pilot study.

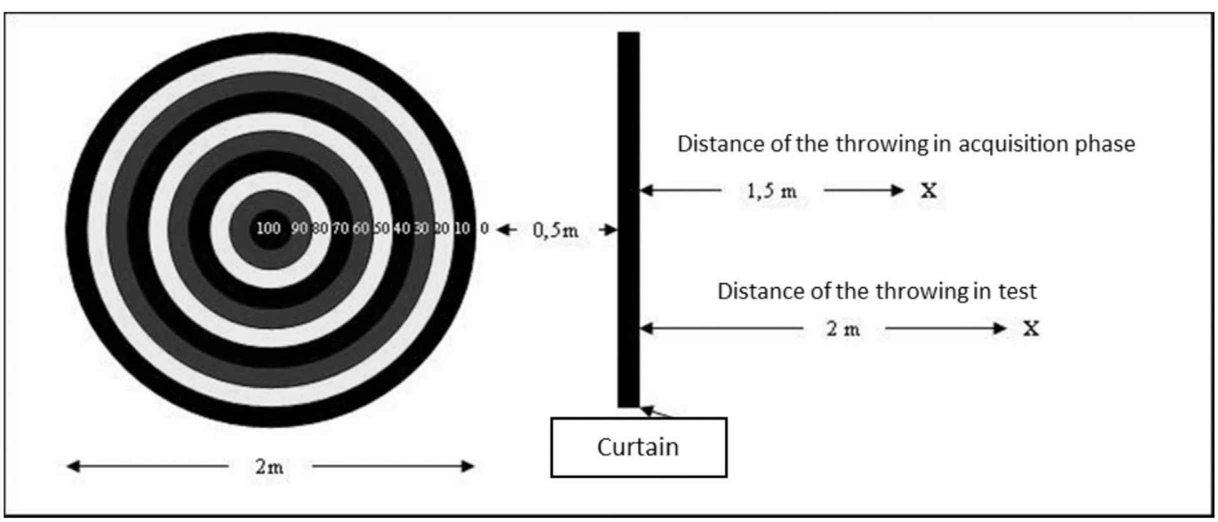

Figure 1 - Diagram of the task used (Chiviacowsky et al.[40]).

Procedures

In the acquisition phase, the individuals made 30 shots at a distance of 2 m from the target and receiving KR according to their experimental group. The volunteers positioned themselves in the throwing area in front of a curtain and made the pitch at the verbal signal of the experimenter. The KR was given verbally, in magnitude (punctuation value) and in direction (long-short and right-left). Three minutes after the acquisition phase, the transfer test was performed with 10 attempts, without KR, of the same pitch, but with the target positioned at 2.5 m.

Results

The data were organized in blocks of 5 trials and the results were analyzed in relation to the mean score and the standard deviation of the score in the acquisition phase and the transfer test (TT) (Figure 2).

Average score

Performance analysis shows a slight improvement in both groups from the 1st trial block to the last of the acquisition phase, with DSG50 performing better than DSG100. In the transfer test the groups maintained similar performances to the last block of the acquisition phase, but with the DSG50 group presenting better performance than DSG100.

One two-way ANOVA (2 groups x 6 blocks) was conducted for the acquisition phase and no significant difference was found between groups [F (1,18) = 1.74, p = 0.21], blocks [F (5,90)] = 2.19, p = 0.06] and the interaction between groups and blocks [F (5, 90) = 1.88, p = 0.11].

For the analysis of the transfer test, a student t test for independent samples was conducted which showed that the DSG50 group presented significantly superior performance [DF (18) = - 2.21, p = 0.04].

Standard deviation score

The consistency analysis of the groups shows similar behavior of the groups. The variability is stable in the first four blocks reducing from the fifth trial block. In the transfer test the DSG50 showed less variability than the DSG100. (Figure 3)

An ANOVA two way (2 groups x 6 blocks) was conducted for the acquisition phase and no significant difference was found between groups [F (1,18) = .44, p = 0.52] and the interaction between groups and blocks [F (5.90) = .93, p = 0.47]. Significant difference was found between trial blocks [F (5, 90) = 2.19, p = 0.06]. Tukey's post hoc test showed that the last

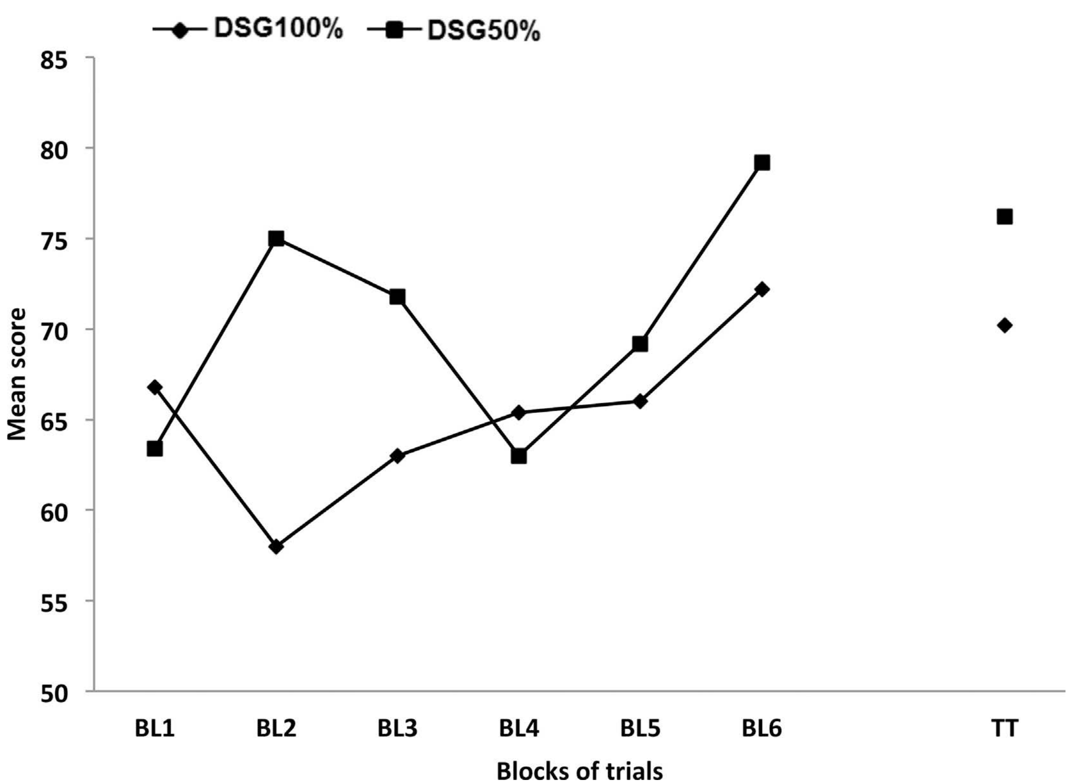

Figure 2 - Mean score and standard deviation in blocks of 5 trials.

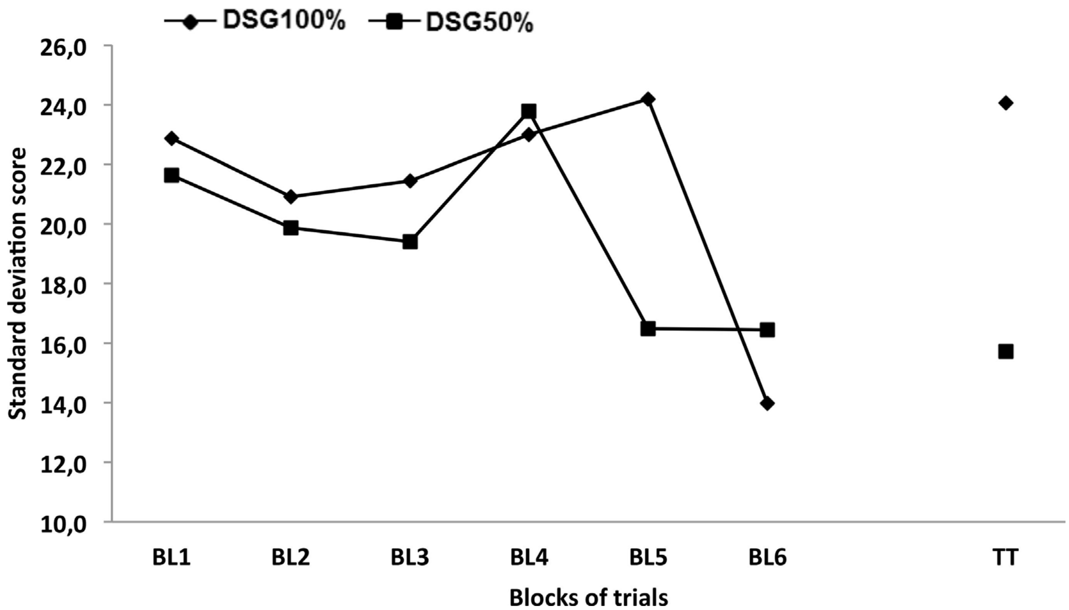

Figure 3 - Standard deviation of the 5-attempt block score.

acquisition block presented less variability than the other trial blocks (p = 0.02).

For the transfer test analysis, a student t test for independent samples was conducted which did not register significant difference between the groups [DF (18) = - 1.79, p = 0.09].

4 Discussion

The present study investigated the effects of relative frequency of KR on motor skill acquisition with individuals with DS. The results found differences between the groups showing that DSG50 presented better performance in the acquisition of the shooting task when compared to the DSG100 group. Regarding the role of reduced frequency of KR in motor skills acquisition, these results are in agreement with the studies by Vieira et al.[20], Ishikura[29], Lai and Shea[30], Lee, White and Carnahan[31], Sparrow and Summers[32], Winsten and Schmidt[34], Oliveira et al.[35] and who found that reduced frequencies are beneficial to the motor skills acquisition process by strengthening the role of intrinsic feedback in the formation of internal structures responsible for movement formation and correction[19]. The learner needs extrinsic information to supplement intrinsic feedback and thus acquire the ability to detect and correct possible errors[32]. It is assumed that at the end of the execution of the movement, the learner processes the cognitive aspects of information, such as goal range, initial condition, response specifications, sensory consequences and the production of movement[42]. The individual processes information derived from the parameters established by the relationship between intrinsic information and KR, thus developing a certain level of control for attempts without KR. The absence of the KR in these attempts tends to keep the objective of the action and the initial conditions unchanged. With the presentation of the KR, the relationship between response specifications and sensory consequences strengthens, contributing to the refinement of corrections, providing a more effective learning. When KR is not available, the learner tends to maintain the relationship between the response and its consequences on subsequent attempts until receiving KR again when he will be able to assess whether the relationship is correct or not[35].

The expectation that cognitive impairment could impose an increase in the relative frequency of KR for the learning process was not confirmed. Thus, the explanation for the present result is the same mechanism seen in individuals without DS, the effect of reducing the frequency of KR delivery and its tendency to decrease information dependence. The KR has the ability to guide the learner to the correct answer. However, with high KR delivery rates, the individual is compelled to rely only on supplemental information thus creating a reliance on extrinsic feedback[21]. When extrinsic information is available, it tends to decrease attention levels by diverting the concentration of intrinsic information, which may decrease the ability to detect and correct errors[31,43]. Thus, reduced relative frequencies tend to strengthen the information processing mechanism and consequently the use of intrinsic feedback even in conditions of cognitive impairment, since the skill requirement level is in the condition of the individual. This explanation illustrates the behavior of the DSG50 in which the 50% frequency was more effective than the group with 100% KR presentation. Individuals with DS only process information more slowly, but use the mechanism to become skilled in the same way as individuals without DS[36,37].

In short, the reduced frequency of KR used (50%) showed better results compared to the high frequency of KR delivery. However, aspects such as the level of cognitive impairment imposed by the syndrome and the complexity of the task should be evaluated for more consistent results on the effect of KR frequency on cognitive impairment conditions as seen in DS.

AI use statement

No AI was used in this research.

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Data availability statement

We declare, for all due purposes that there search data is available in the body of the document.

Conflict of interest statement

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report.

Author contributions (CRediT)

Cleber de Souza Lopes: conceptualisation, investigation, methodology, data curation, writing - original draft, writing - review and editing, visualization, writing - review and editing. **Bruno Roberto dos Santos:** conceptualisation, investigation, methodology, data curation, writing - original draft. **Márcio Mário Vieira** conceptualisation, investigation, methodology, data curation, writing - original draft, visualisation, writing - review and editing.

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