GYMNASTS UTILIZE VISUAL AND AUDITORY INFORMATION FOR BEHAVIOURAL SYNCHRONIZATION IN TRAMPOLINING

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ABSTRACT: In synchronized trampolining, two gymnasts perform the same routine at the same time. While trained gymnasts are thought to coordinate their own movements with the movements of another gymnast by detecting relevant movement information, the question arises how visual and auditory information contribute to the emergence of synchronicity between both gymnasts. Therefore the aim of this study was to examine the role of visual and auditory information in the emergence of coordinated behaviour in synchronized trampolining. Twenty female gymnasts were asked to synchronize their leaps with the leaps of a model gymnast, while visual and auditory information was manipulated. The results revealed that gymnasts needed more leaps to reach synchronicity when only either auditory (12.9 leaps) or visual information (10.8 leaps) was available, as compared to when both auditory and visual information was available (8.1 leaps). It is concluded that visual and auditory information play significant roles in synchronized trampolining, whilst visual information seems to be the dominant source for emerging behavioural synchronization, and auditory information supports this emergence.

KEY WORDS: visual information, auditory information, straight leaps, trampolining, behavioural synchronisation

INTRODUCTION

In synchronized trampolining, two gymnasts perform the same routine at the same time on trampolines placed side by side [3]. Trained gymnasts are thought to coordinate their own movements with the movements of another gymnast by detecting relevant movement information [9]. The gymnast on the first trampoline can (peripherally) see the gymnast on the other trampoline. He/she can also hear the sounds of the other gymnast's leaps on the trampoline. The question arises how visual and auditory information contribute to the emergence of synchronicity between both gymnasts. Therefore the aim of this study was to examine the role of visual and auditory information in the emergence of coordinated behaviour in synchronized trampolining.

Behavioural synchronization processes may occur in rather simple interpersonal bimanual coordination tasks [12], more complex everyday tasks [10,14], as well as more complex sport-specific skills [11]. Recent theoretical approaches argue that the emergence of interpersonal coordination may rely on shared internal representations between action perception and action planning as well as action execution, since these representations allow for predicting other peoples' actions [1,8,13].

Behavioural synchronization processes may thus occur between two actors when they are connected on an informational level, with each actor utilizing his/her internal representations of the experimental task to predict the movement of the other actor. Richardson et al. [10] investigated for instance interpersonal coordination between two people rocking chairs. The authors could show that people tended to coordinate their rocking, and that the amount of coordination was dependent on the availability of visual information about each co-actor's movement. Visual information can thus couple the movements of interacting individuals, but there is additional evidence that an auditory coupling may constrain rhythmic (limb) movements between individuals, such as when clapping one's hands together with other people [7].

It is argued that behavioural synchronization may occur between two gymnasts when they are connected on an informational level [11]. Behavioural synchronization is furthermore a key element in synchronized trampoline since it is an important judging criterion, and therefore directly related to a successful performance [3]. However, it is still questionable which role visual and auditory information play in the emergence of coordinated behaviour in synchronized trampolining. To address this question, different informational sources of one gymnast were systematically manipulated while she was asked to synchronize her performance with another gymnast. It was hypothesized that gymnasts exhibit behavioural synchronization faster, and that behavioural synchronization is more stable when sensory information is not constrained.

MATERIALS AND METHODS

Participants. Twenty female gymnasts (M_{age} = 14, SD = 3 years) participated in this study. They reported to have regional experience such as participation in the regional trampoline championships. They had an average training experience of seven years and practised on average six hours per week. The gymnasts were informed about the general procedure of the study and gave their written consent prior to the experiment, which was carried out in accordance with the universities' local ethical committee. It was decided to recruit experienced gymnasts since it was thought that stronger synchronization processes might occur in people who are specifically trained in a particular task, and because they already possess appropriate task-related internal representations [1,11].

Task and Measures

The experimental task was to perform straight leaps on a trampoline in three experimental conditions. Two trampolines were arranged as they would be in an international competition in synchronized trampolining with elevated safety mats behind and in front of the trampolines as well as with safety mats placed on both long sides. While a model gymnast performed straight leaps with a flight duration of 1 s, the other gymnast was instructed to synchronize her leaps to the leaps of the model gymnast. Sensory information was manipulated in three experimental conditions. The first experimental condition reflected gymnasts' natural situation in synchronized trampolining, and both gymnasts performed side by side on the two trampolines (*full visual and auditory information condition*). In the second experimental condition, the two gymnasts performed side by side with the participating gymnast wearing ear protection limiting auditory information (*constrained auditory information*). In the third experimental condition, the trampoline of the model gymnast was placed two metres behind the trampoline of the participating gymnast, so that the participating gymnast could hear but not see the other gymnast (*constrained visual information condition*).

In order to assess the temporal coordination of both gymnasts, a digital video camera was placed 15 m away from and orthogonal to the joint cross axis of both trampolines (sampling rate: 240 Hz). It was elevated to a height of 2.50 m so that it pictured the feet of both gymnasts when they were in contact with the trampoline bed during each leap. The absolute values of the gymnasts' touchdown points in time were analysed. Each touchdown point was defined as the first visible contact of the gymnasts' feet with the trampoline bed. From the analysed values, first, the number of leaps was calculated until both gymnasts performed synchronously. Synchronicity was defined as the point in time when the temporal difference between the touchdowns of both gymnasts prior to the take-off phase was less than 0.04 s. It was decided to choose this value as the criterion for synchronicity because it matches the average critical flicker fusion threshold in healthy adults and may thus be an indicator of perceiving two events as temporally similar [2]. Second, the mean absolute temporal error between the touchdown points of both gymnasts was analysed as an indicator of maintaining synchronicity. Therefore, the absolute differences between the touchdown points of both gymnasts during five subsequent leaps after reaching synchronicity were averaged [5].

Procedure

The experiment was conducted in three phases. In the first phase, the participating gymnast arrived at the gym and signed the informed consent form. She was given a 15-minute warm-up phase to ensure that she was physically prepared. In the second phase the participating gymnast was asked to perform straight leaps on the trampoline from a standing position in three experimental conditions whilst trying to synchronize her leaps with a model gymnast performing on the second trampoline. The model gymnast was instructed to perform straight leaps with 1 s duration (predetermined by an optic metronome that was visible to the gymnast only). The performances of both gymnasts were videotaped. The participating gymnast was furthermore instructed to perform seven additional leaps when she perceived her jumps in synchrony with the model gymnast before stopping the current trial. The three experimental conditions were presented in a random order for each gymnast. There was no time pressure in this study and the participating gymnast was allowed to take breaks as requested. In the third phase of the experiment the participating gymnast was debriefed.

Data Analysis

A significance criterion of α = 5% was established for all reported results. In order to assess differences between the three experimental conditions, first, separate univariate analyses of variance (ANOVAs) with repeated measures were calculated, taking the number of leaps prior to reaching synchronicity as well as the mean absolute temporal error for maintaining synchronicity as dependent variables. Post-hoc analyses were carried out using Fisher's LSD post-hoc tests. Cohen's f was calculated as an effect size for significant effects.

RESULTS

Manipulating sensory information revealed a significant effect on the number of leaps prior to reaching synchronicity, $F(2, 38) = 8.338$, $p < 0.05$, Cohen's $f = 0.66$. The results are presented in Figure 1. Post-hoc analysis revealed that gymnasts needed more leaps to reach synchronicity when only auditory information was available as compared to when only visual information or visual and auditory information was available. Furthermore, gymnasts needed more leaps to

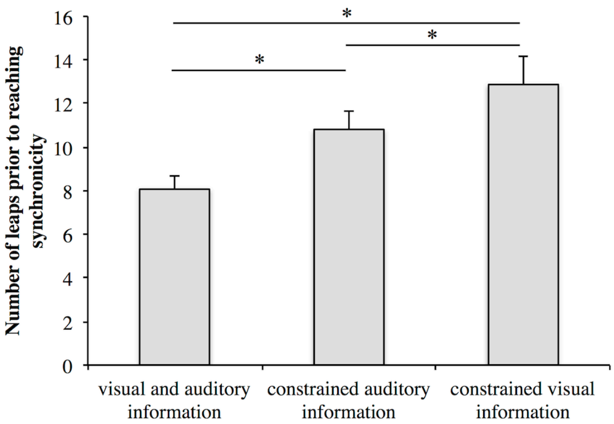

FIG. 1. NUMBER OF LEAPS PRIOR TO REACHING SYNCHRONICITY WITH REGARD TO THE AVAILABLE SENSORY INFORMATION
Note: Data are presented as means ± standard errors; * denotes significant difference in number of leaps according to post-hoc test.

reach synchronicity when only visual information was available as compared to when visual and auditory information was available. There was, however, no significant effect for manipulating sensory information on the mean temporal error for maintaining synchronicity, $F(2, 38) = 0.780$, $p = 0.465$. The mean temporal error for maintaining synchronicity was 0.038 ± 0.005 s in the unconstrained condition, 0.041 ± 0.006 s when auditory information was constrained, and 0.047 ± 0.006 s when visual information was constrained (means ± standard errors). Gymnasts exhibited on average the same temporal error for maintaining synchronicity in all three experimental conditions.

DISCUSSION

Taking the results of the current study together, it becomes apparent that gymnasts are able to synchronize their performance with the performance of another gymnast when they are coupled on an informational level [11]. This coupling may appear on a visual level, on an auditory level or on both levels in synchronized trampolining. Relying on both visual and auditory information may lead to faster behavioural synchronization in trampolining, while constraining either visual or auditory information results in slower behavioural synchronization, indicating that both visual and auditory information are used in coordinating straight leaps between two gymnasts in synchronized trampolining. From the current results, it is argued that visual information most directly guides the coordination process and thus more strongly couples the two gymnasts. An advantage of relying on visual information is that it enables one gymnast to anticipate the touchdown point of another gymnast from concurrent visual input [4]. As a consequence, the gymnast might be able to anticipate the necessary corrections for the subsequent leap already while she is in the air during the current leap. In this sense it may enable the gymnast to faster adapt her flight duration to that of the other gymnast [6].

However, visual information alone might not explain the coordination process, because gymnasts needed more leaps to reach synchronicity when visual information was available but auditory information was constrained. Therefore, it is argued that hearing the sound of the other gymnast during take-off might enable the gymnast to estimate the catapult force of the trampoline, which in turn determines the flight duration of the other gymnast, and thus may support the prediction of the other gymnast's subsequent leap. This may be especially the case if the gymnast is experienced in performing straight leaps with differing flight durations. Auditory information alone might be sufficient to maintain synchronicity. This may be especially important when it comes to more complex movement situations, such as when gymnasts perform multiple somersaults with twists where it seems to be impossible to visually perceive the gymnast on the other trampoline.

CONCLUSIONS

Visual and auditory information play significant roles in synchronized trampolining. Visual information seems to be the dominant source for emerging behavioural synchronization, whereas auditory information supports this emergence. Maintaining synchronicity may rely on visual information, auditory information, or both. However, the complexity of the situation may determine which informational source may be suited best.

Conflict of interest: The authors report no interests or conflicts.

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