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EFFECT OF THE AMOUNT OF ALLOWED VISUAL INFORMATION ON ACROBATIC SKILL LEARNING

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ABSTRACT

Postural control is the result of different sensorial information integration. During complex movements, such as acrobatic skills when a subject jumps and turns on the transversal axis, sensorial conflicts can appear, especially among visual and vestibular inputs. The importance of these conflicts during learning and posterior execution of an acrobatic manoeuvre is not clear. An experimental study was carried out where we controlled the environmental illumination of flying and landing phases of an acrobatic skill execution (forward tucked somersault) during the learning process. We obtained significant differences between different practice groups, showing better results those subjects who accomplished their practice without illumination during the landing phase. Our results suggest that although visual information might be important to perform the take-off phase correctly, it doesn't seem to be a determining factor on its final phase (landing) and could even interfere with vestibular information.

KEYWORDS: sensorymotor integration, vision, vestibular information, acrobatic activities

RESUMEN

El control postural es el resultado de la integración de diferentes informaciones sensoriales. En la ejecución de movimientos complejos, como las habilidades acrobáticas basadas en saltar y girar en torno al eje transversal, pueden aparecer conflictos sensoriales, especialmente entre la información visual y la vestibular. La repercusión de estos conflictos sobre el aprendizaje y dominio de este tipo de habilidad no esta clara. Se realizó un estudio experimental, en el cual la iluminación del ambiente fue manipulada en las fases de vuelo y aterrizaje durante la etapa de aprendizaje de una habilidad acrobática típica (mortal hacia delante agrupado). Se obtuvieron diferencias significativas entre grupos experimentales, mostrando mejores resultados los sujetos de los grupos que practicaron sin iluminación durante la fase de aterrizaje. Nuestros resultados sugieren que, aunque la información visual puede ser importante en el control de la fase de impulsión, parece no ser un factor determinante en la última fase (aterrizaje) e incluso podría interferir con la información vestibular.

PALABRAS CLAVE: integración sensorio-motriz, visión, información vestibular, actividades acrobáticas

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1. INTRODUCTION

The goal of postural control is to orient body parts relative to one-another and the external world without loss of balance. Posture must be controlled both while the body is still (static equilibrium) and during movement (dynamic equilibrium). Human postural control can involve several different sensory modalities, e.g. the visual, vestibular and somatosensory systems. Moreover, it has previously been shown that afferent visual, vestibular and propioceptive input converge in the neural generation of an egocentric, body-centred coordinate system that allows us to determine our body position with respect to visual space (Karnath et al., 1994; for a review, see Andersen et al., 1993) and the posterior parietal cortex is the most prominent area of the brain involved in such transformations (Sakata and Kusunoki, 1992; Andersen et al., 1993).

However, sensorial conflicts can arise. Apparent visual self-motion is a good example and is a quite common experience. It can be perceived while gazing at moving clouds (feeling of movement or imbalance), or while sitting on a stationary train viewing a moving train on the adjacent track (who is moving?). In these situations we have contradictory visual and vestibular input, and it has been shown recently that an inhibitory visual-vestibular interaction exists which protects visual perception of self-motion from potential vestibular mismatches caused by involuntary head accelerations during locomotion (Brandt et al. 1998).

There are situations in life that involve very complex motor behaviour, and where interactions among control systems can become problematic. Good examples are athletes who perform acrobatic activities such as whole body forward rotations in the air (forward somersault). In this situation and at the end of the movement the athlete must land and maintain balance. To accomplish this motor act the brain has to integrate vestibular, visual and propioceptive information. Because of the temporal differences in the responses times of the different sensory modalities (Kamen and Morris, 1988) we questioned whether vision provides a useful input to this task or represents a source of conflict. We have addressed the issue by studying human volunteers who learned to perform an acrobatic jump in different situations of environmental illumination.

2. METHODS

Thirty five healthy young volunteer students participated in the study, aged 18 – 24 years (eight females and twenty seven males), each giving their written, and informed consent. None of the participants had previously had any training in this particular discipline: the execution of basic acrobatic skills. Eight experienced gymnastics coaches participated during the learning phase. Pre and post test phases were evaluated similar to the procedures used in the artistic gymnastics competition. Evaluation sheets were written up and filled in by two well-trained observers.

Figure 1 schematically illustrates the set up for this work. Subjects were located on a plinth (A) from where they jumped on to a minitramp (B) thereby initiating the acrobatic movement, and finally landing on a soft mat (C). Two pairs of photoelectric cells (E) allowed us to control illumination on-line, (represented here by two lamps, F) during all phases of the exercise from the initial jump to the completed landing.

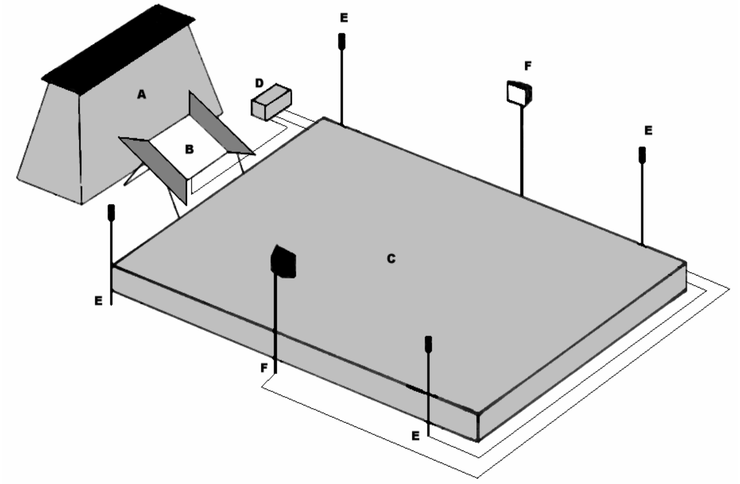

Figure 1. Diagrammatic illustration of the experimental set-up: A. Plinth; B. Minitramp; C. Competition mat; D. Connections box; E. Photoelectric cells; F. Lamps.

Two experimental measures (dependent variables) were established based on the performance of a “forward tucked somersault”, performed in the pre and post test in full and complete room lighting:

- *Performance quality*. A measure of the correct technical performance during the jump and the aerial phase of somersault. Fifteen technical requirements were defined to be evaluated. The variable measure was the amount of requirements accomplished in three executions (range of values from 0 to 45 points).
- *Landing efficiency*. A measure of the gymnastic skill level in making the somersault landing. Like in gymnastics competition, we defined beforehand the amount of points (deduction points) corresponding with each landing, taking into account the kind, number and size of supports to reach balance. The measure values were inversely proportionate to the landing efficiency scores obtained: more points meaning a worse balance process (range of values from 0, the best, to 201 points, the worse).

We have considered the relation among these variables since the actions during the aerial phase can affect some factors, such as body angular velocity at touchdown. However, the *landing efficiency* variable was necessary to know the various approaches in resolving the lack of balance at the end of the movement.

These measurements were taken before and after the training period. Subjects were assigned to one of four groups for training (see below). During training, visual information was manipulated by the interruption of lighting in the experimental room. The four groups were trained under the following conditions (independent variable):

- Group I: Continuous lighting throughout.

- Group II: Lighting during take-off and while executing the manoeuvre. Suppression at touch-down, until the end of the trial.
- Group III: Lighting during take-off only. Suppression at the moment the subject leaves the trampoline, until the end of the trial.
- Group IV: Lighting during take off. Suppression at the moment the subject leaves the trampoline. Lighting restored at the moment of touch-down.

There were 6 phases to the experimental protocol:

- Phase 1. Training of the observers. The aim was to obtain the highest precision using registering data forms and an interobservers reliability rate higher than 80 % (Anguera, 1990).
- Phase 2. Participant's basic learning of the skill to be performed previous to the experimental phase.
- Phase 3. All the participants did motor coordination and balance basic tests to discard those ones with disorders which could have influence on the results of study.
- Phase 4. PRETRAINING test: each subject received initial instructions (same for all groups); six vertical preparatory jumps from the minitramp to the landing mat were executed as well as three trials of the complete acrobatic manoeuvre, with lighting. Between trials subjects had rest and concentration periods. Pretraining data was then used to distribute the subjects homogeneously into the four experimental groups to avoid significant differences between groups. Some subjects did not finish the training period (Phase 5), and therefore they were excluded from the study. This explains why the four groups had a different number of participants.
- Phase 5. Intense training phase: each group trained in the lighting conditions assigned to them. Training for all groups consisted of three sessions. During each session they had to perform twelve trials, distributed in four series of three trials each. Prior to execution, they each had a short warm up period of general gentle exercise and performed three jumps from the minitramp to the landing mat.
- Phase 6. POSTRAINING test: this took place the day after the end of the experimental training phase, using the same procedure as the pre-training test.

3. RESULTS

3.1. PRETRAINING test

The score in *performance quality* and *landing efficiency* obtained by the subjects in the pretraining test is shown in table 1. The Kolmogorov-Smirnov test was applied in order to show that the within group data corresponded to a normal distribution. After that, the ANOVA test was carried out showing no significant differences between groups (different level of independent variable) for the two measures ($p > 0,05$, table 3). Variances' homogeneity was checked before using those data.

Table 1. Points obtained in pretraining measures.

Subject	*PERFORMANCE QUALITY*				*LANDING EFFICIENCY*			
	GroupI	GroupII	Group III	Group IV	GroupI	GroupII	Group III	Group IV
1	28	38	32	37	20	17	26	25
2	31	41	36	39	8	12	9	10
3	33	31	33	30	28	19	6	23
4	40	42	36	34	13	7	45	21
5	30	34	31	31	8	29	57	23
6	31	27	36	32	9	47	11	24
7	26	27	27	29	26	15	14	47
8	22	31		38	62	15		38
9	33	25		20	47	54		12
10	28				30			
Mean	30,2	32,888	33	32,222	25,1	23,888	24	24,777
SD	4,802	6,273	3,116	5,826	17,922	16,289	19,798	15,573

3.2. POSTRAINING test

Table 2 illustrates the score obtained in these measures after training. Again the Kolmogorov-Smirnov test demonstrated that in-group data followed a normal distribution. In this case the ANOVA test showed significant differences between groups ($p < 0,05$, table 3). In order to localize those differences, the ANOVA test with multiple comparisons (table 4, Scheffe's method) was used. Once again, variances' homogeneity was checked beforehand.

Table 2. Points obtained in postraining measures.

Subject	*PERFORMANCE QUALITY*				*LANDING EFFICIENCY*			
	GroupI	GroupII	Group III	Group IV	GroupI	GroupII	Group III	Group IV
1	33	31	40	33	72	7	5	12
2	26	41	39	33	12	4	10	55
3	35	37	30	24	8	8	7	47
4	27	40	37	34	25	6	5	17
5	36	39	34	29	11	4	12	71
6	33	36	34	24	9	10	22	11
7	27	30	33	32	27	11	12	87
8	21	37		34	22	9		6
9	33	36		25	38	5		46
10	30				7			
Mean	30,1	36,333	35,285	29,777	23,1	7,111	10,428	39,111
SD	4,748	3,741	3,545	4,352	19,969	2,571	5,912	29,118

Table 3. Differences between groups in pre and pos-training data. ANOVA Test.

	Pre-training		Post-training	
	F	P value	F	P value
PERFORMANCE QUALITY	0,563	0,644	5,912	0,003
LANDING EFFICIENCY	0,012	0,998	7,014	0,001

Table 4. Post-training data. Multiple pair comparison. *Scheffé* Method (p value).

	PERFORMANCE QUALITY				*LANDING EFFICIENCY*			
	GROUPI	GROUP II	GROUPIII	GROUPIV	GROUPI	GROUP II	GROUPIII	GROUPIV
GROUP I		0,027*	0,119	0,999		0,014*	0,333	0,920
GROUP II	0,027*		0,969	0,022*	0,014*		0,607	0,003**
GROUPIII	0,119	0,969		0,099	0,333	0,607		0,127
GROUPIV	0,999	0,022*	0,099		0,920	0,003**	0,127	

*p < 0,05
**p < 0,01

In terms of *performance quality*, group II showed better results, this group being the one that trained without lighting at the moment of contact with the landing area (fig. 2). This group showed better technical execution (*performance quality* score, table 2, table 4; p<0,05) than the other two groups, who had trained with lighting during the landing phase (I and IV, Scheffe's method). Of the remainder, only group III showed improvement in the element *performance quality* mean, even though results were not statistically significant. We wish to emphasise that both groups II and III had a training phase without lighting during contact with the landing area.

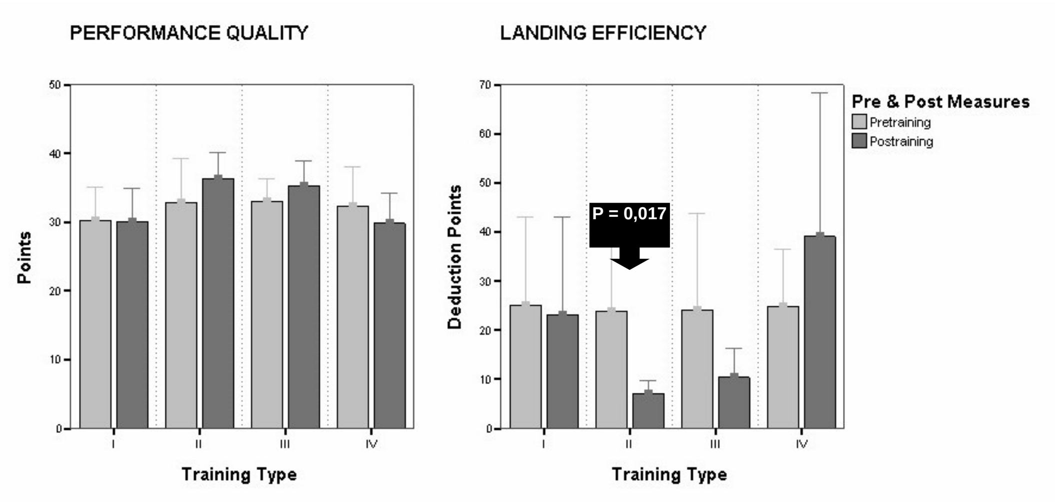

Figure 2. Pretest and postest mean score obtained by group for each variable. Error bars show +/- SD mean.

In *landing efficiency*, training has had significant effects, with differences between groups of p=0,001 (table 3). Once more, group II displayed better results, showing significant differences compared to groups I and IV (Scheffe's method) which both had lighting during contact with the landing mat in the training phase (table 4, p<0,05).

To analyze the training type effect over the two variables, we applied to every measure and each experimental group, the Student T test for two related samples. We only found significant improvement in group II referring to the pretraining *landing efficiency* ($p < 0.05$, Student T test). However the graph (fig. 2) shows that the two groups (II and III) that trained without lighting during landing, had the greater improvements in the mean of *landing efficiency* (less deduction points) whereas group IV's performance worsened.

4. DISCUSSION

It seems that repeated practice in restricted visual information conditions could have an effect upon the use of other information involved in the control of a skilled manoeuvre, (such as vestibular, propioceptive and tactile sensations). The interaction between vision and the other sources of sense information seems most telling around the time of touch-down/landing. We put forward a hypothesis that fast processing of vestibular information generated by semicircular channels due to changes in angular motion at the landing moment seems to be a good control mechanism, which is degraded by the additional information given by the visual system. It is interesting to note that data obtained in other studies show that, in controlling balance, subjects tend to choose visual information rather than propioceptive information, and that this usually happens during learning (Nashner and Berthoz, 1978; Berthoz et al., 1979). Use of visual information during the learning period would allow a negative influence of the vestibular ocular reflex on the landing. To stop rotation suddenly on the transverse axis at the moment of contact with the mat, as usually happens to beginners, could introduce harmful visual sensations during the last part of the skill due to the nistagmus produced by this reflex reaction. Reducing the possibility of this sensorial conflict would help to assimilate the right actions in order to control the experimented movement.

If we consider the theories of Pozzo and Studeny (1987) and Pozzo (1988) on the control of acrobatic jumps during the take-off and landing phases based on "egocentric" references, which include central vision, propioceptive and kinaesthetic information, we can infer that group II improved mainly in the use of the last sensorial channel. Foveal vision could also take part in the landing during the learning period, since lighting conditions in this group allow the participants to use it just before contacting the landing mat. However, we must also consider Liebermann (1991) who observed plantar landings executed in darkness, showing that muscle responses appeared noticeably sooner than those seen in lit conditions. Repeated practice without light just before landing could trigger anticipatory responses in the muscles responsible for absorption of kinetic energy at touch-down.

These results contradict to some extent Rezette (1983) and Lee et al. (1992), whose results indicated a more accurate control of landing after rotation by the use of visual information. It should be noted, however, that their studies were done without lighting throughout the execution of the manoeuvre and without differentiating the amount of visual information available during the various phases of the exercise. Under these practice conditions, an incorrect takeoff due to the lack of vision could have had a negative influence on the reception results. Finally they did not consider the effect of repeated practice in restricted information conditions. The perception of body orientation in space depends on multisensory evaluation of visual, vestibular and propioceptive sensory input. When vision is excluded, the vestibular system, which registers position and motion of the head in space, and propioceptive information from the neck region act together to relate trunk to space; this is called vestibular-propioceptive interaction as was originally introduced by Roberts (1973). Since then several lines of evidence from experimental work in animals have supported this idea (Pompeiano, 1988) and it has been recently shown that visual, vestibular and propioceptive inputs contribute to the neural generation of the reference frames that underlie mental representation of space in egocentric coordinates (Dichgans and Brandt, 1978; Karnath et al., 1994). Furthermore, an inhibitory visual-vestibular interaction has been proposed as a mechanism that might protect visual perception of self-motion from potential vestibular mismatches caused by involuntary head acceleration during locomotion (Brandt et al., 1998). Although our experimental situation is obviously different, the data presented here suggest that such an interaction might also exist when the learning of a complex motor behaviour is considered. In the case of lights out during flight there is no competition between VOR (vestibular ocular reflex) and saccadic eye movements (although it is questionable whether individuals made any directed saccades during flight), meaning that parietal input would be minimal. VOR cancellation or termination following flight would be affected if there were no saccadic targets available; therefore we propose (as a hypothesis to be tested in the future) that "stability" on landing is enhanced because the individuals trained in darkness have opted not to "engage" parietal saccade control.

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