The effect of visual feedback during stick balancing

László Bencsik[1], Dalma J. Nagy[2] and Tamás Insperger[1,2]

[1] *MTA-BME Lendület, Human Balancing Research Group,{bencsik, insperger}@mm.bme.hu*
[2] *Department of Applied Mechanics, Budapest University of Technology and Economics, nagy.dalma22@gmail.com*

How humans perform different balancing task, such as stick balancing at the fingertip or simple bipedal stance, can be viewed as a complex control problem. Information is transmitted by neurons to and from the brain that controls muscle groups in a synchronized process. The nature of the decisions and commands made by the nervous system during this simple task is still not entirely understood and is subject of neurobiological research. In order to characterize the principles of human balancing, stick balancing is studied with respect to different sensory conditions [1, 2]. In stick balancing tests in the literature, the stick usually balanced on the fingertip. In this case information is based on visual feedback from the eyes and force feedback from the mechanoreceptors of the skin at the fingertip. The goal of this study is to analyze the performance of the balancing task when these sensory information sources are altered.

In this work, two measurements scenarios are tested. The first measurement configuration is the classical stick balancing on the fingertip (see the left hand side of Fig. 1). In the second scenario, the stick is balanced on a table tennis racket (see the right hand side of Fig. 1). In this configuration the contribution of the mechanoreceptors to the control process is limited, because there is no direct contact between the fingertip and the stick.

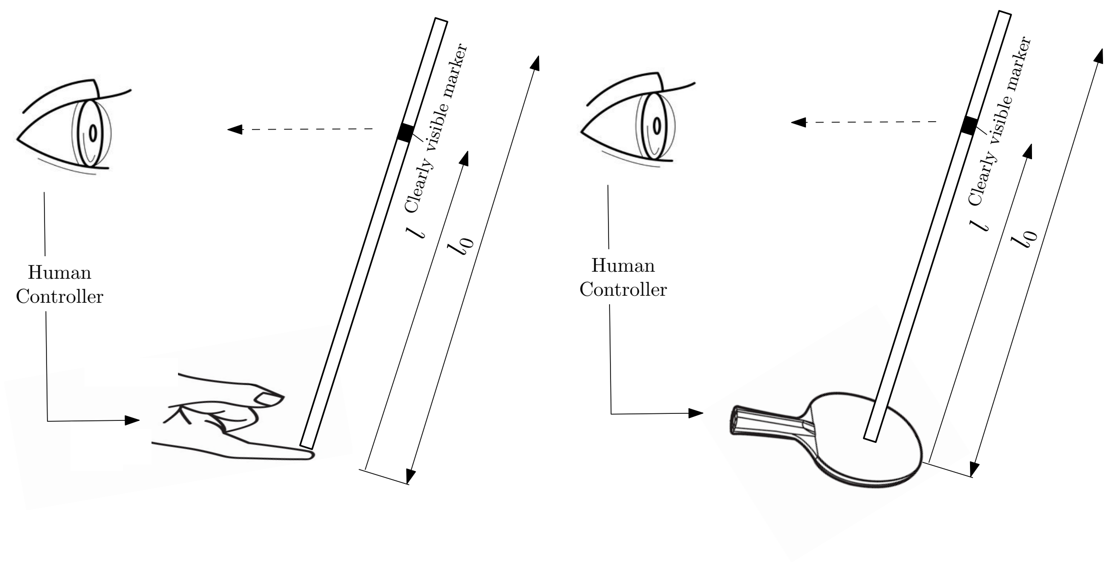

Fig. 1: The measurement scenarios: stick balancing on the fingertip (left) and on a table tennis racket (right).

In order to see the effect of the visual feedback in both measurement scenarios, a red marker was attached to the stick as shown in Fig. 1. The subjects were asked to keep the focus on this marker during balancing. For the first measurements, the position of the red marker form the top of the stick was $d = l_0 - l = 1$ cm. After a successful balancing trial, the marker was replaced further from the top (closer to the bottom) by 10 cm, thus d was changed to 11 cm, 21 cm, etc in the subsequent measurements. A measurement was considered to be successful if the subject was able to balance the stick for 60 seconds at least once out of 8 trials. The measurement was terminated when the subjects were not able to perform a successful balancing trial. The length of the stick was $l_0 = 84$ cm.

Since visual perception is probably the most important source of information during stick balancing, it is expected that the balancing task becomes more and more difficult as the distance d of the red marker from the top of the stick is increased. It was assumed that if d exceeds a critical value then the subjects cannot stabilize the stick about its the upward vertical position. The measurements were recorded with an OptiTrack motion capturing system, and the angular deviation from the vertical direction was calculated as a function of time. Furthermore, the average of the absolute value of this angle was also calculated for each measurement.

The results of the measurements are summarized in Fig. 2. The results for balancing on the fingertip are shown on the left hand side panel, while the panel on the right hand side shows the results obtained for balancing on a table tennis racket. It can be seen that, as anticipated, the average angle becomes larger as the position of the marker is gets lower along the stick. A reasonable explanation to this phenomenon is the following. It is assumed that human subjects make a corrective motion if the horizontal displacement of the marker measured from the bottom of the stick reaches a threshold. This relation can be given as

$$\varphi = \frac{l_0\ \varphi_0}{l} = \frac{l_0\ \varphi_0}{l_0 - d}, \tag{1}$$

where φ is the threshold of the angle deviation from the vertical when the subject concentrates on the marker and φ_0 is the threshold angle when the subject concentrates on the top of the stick. Thus, theoretically, the average angle as a function of distance d is a hyperbola, which is shown by dotted line in Fig. 2. It can be seen that the tendency of both measurement scenarios are similar to the theoretical one. The measurements show that it is not possible to balance the rod if the marker is below the half of the stick, which corresponds to the theoretical results of literature [3]. An important observation is that it was more difficult to balance the stick with a given marker position on the racket, because force feedback perception is negligible in this measurement configuration. Based on these measurements, it can be concluded that the gain of the visual feedback and its threshold have a large effect on stick balancing performance, especially if only the visual feedback is available. In order to draw more precise conclusions the measurements have to be repeated with a larger number of subjects.

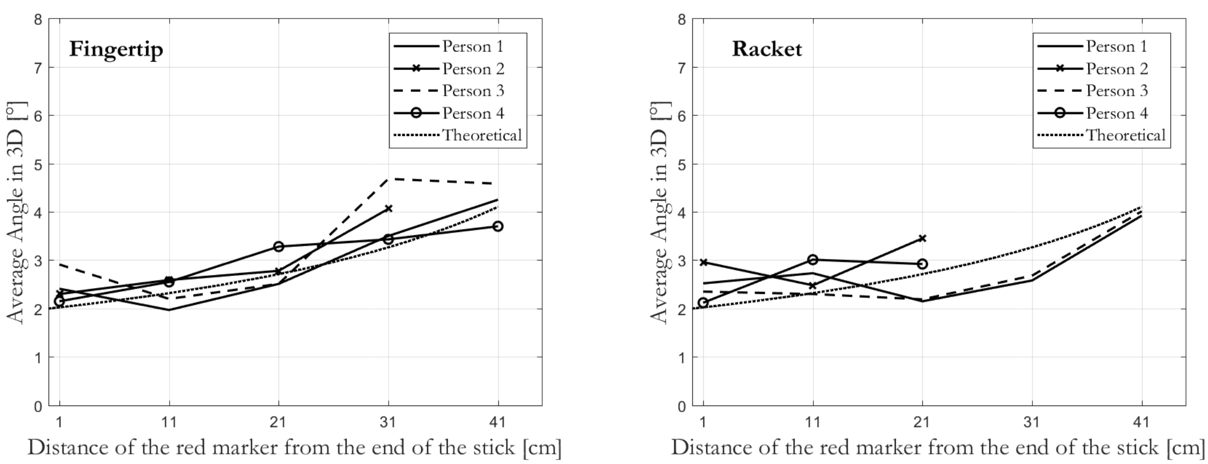

Fig. 2: The results of the measurements.

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References

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