Use of Human Simulation in Workplace Design

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Abstract

This paper describes and evaluates the use of the Jack 2.1 computational tool in the process of workplace design, from the standpoint of the concepts of simulation and ergonomics. The results reveal how some design factors were coherently dimensioned, taking into account the human factors involved, particularly in anthropometric terms. It was concluded that this tool can greatly aid the designer's activity, provided it is incorporated into a holistic approach, integrating principally the organizational and cognitive aspects inherent to human activity.

Keywords: Human Simulation and Modeling, Workplace Design, Ergonomics, Health and Safety Worker.

1. Introduction

Workplace design has been studied for many years, starting in the 20th century, when it gradually became clear that systems and products would have to be designed taking into account human and environmental factors, and whether they would be used safely and according to their purpose (MacLeod, 2003).

The almost natural process of man making analogies through the use of models whose behavior resembles that of the object under study has been extremely valuable in the development of the science, originating what today is known as simulation, which, according to Costa (2004), can be defined as the process of construction of a representative model of a real system and its subsequent experimentation. The results of experimentations, after their analysis, provide a probable future vision of the system. The information thus generated underpins decisions required in the present and contributes to a better understanding of the system studied.

Human simulation uses the benefits of virtual reality and of graphic computation for applications in the field of industrial facilities design and in the conception, evaluation and implementation of production systems that involve humans. Its use has gained ground rapidly, particularly in large companies and institutions (Braatz et al. 2002).

2. Ergonomics and Human Simulation

The notion of Ergonomics has progressed as knowledge and practice. Today, altering the work environment and hence, the new modes of production, conditioned by successive mutations of a social, geographic and economic nature, has become increasingly interdependent on the worker's conditions and on the conditions under which he carries out his work. The relations among technical, social and human aspects are ever more complex, thus resulting in a new vision of work (Castillo et al. 2005).

Human simulation has been applied to workplace design, principally with the purpose of adapting man physically to the environment under study. The use of human digital models can anticipate some design factors that enable the rational use of resources to adapt a given element to the greatest possible portion of the potential population of operators. To this end, it is necessary to consider anthropometric data and also to methodically build the human digital models. Although the computational tool does not require it, cognitive and organizational aspects are extremely necessary for simulation since, without them, it is impossible to fully grasp man's interaction with the system under study.

3. Method

Generally speaking, the method employed in human simulation follows the stages of systems simulation, with validation usually occurring after prototyping of the workplace under study.

Figure 1 depicts the principal stages of the process of human simulation.

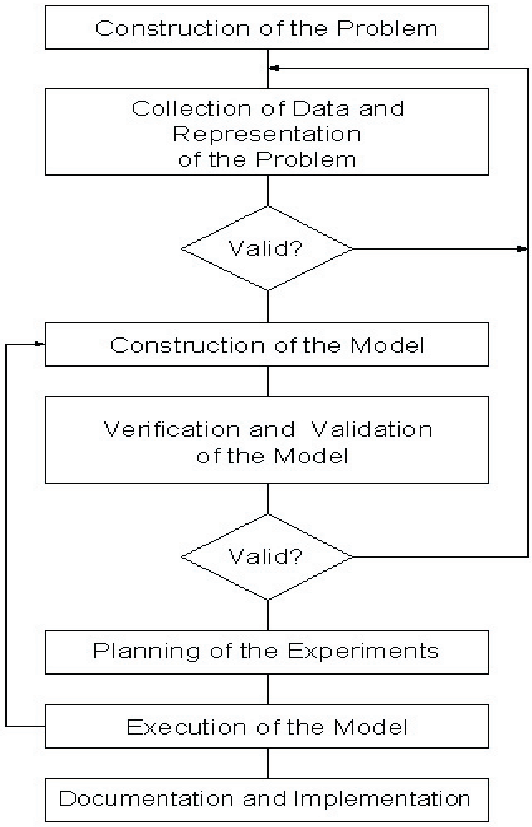

Figure 1. Stages of the process of human simulation (adapted from Costa, 2006)

The definition of the problem and, especially, the delimitation of the ergonomic action, have posed a constant challenge in the process of intervention. In the specific approach of a workplace, the requirement usually involves some type of ergonomic analysis, which may be qualitative or quantitative. Such analyses usually result in strong hypotheses concerning risks to the operator's health and organizational needs.

In this stage of the analysis, it is important that the data be obtained through an analysis of the real activity rather than only from the prescribed work. However, in some cases, the data of this prescription are the only possible ones, which makes them very valuable for the design, since they help eliminate some of the hypotheses about the activity or find the most probable ones

(Castillo et al. 2005).

In such cases and in those where the workplace does not yet exist physically, human simulation is the central tool to conceive and develop designs considering the human factor. The use of this technology enables the design to evolve dynamically, allowing for analyses even before the physical prototyping phase, i.e., it contributes, among other things, to a representation closely resembling the real problem.

In the specific case analyzed in this work, a hand packaging table had to be designed for a manufacturer of school material. The main products packaged on this table are felt-tipped and ball-point pens, mechanical pencils and plastic pencil sharpeners.

Based on analysis of the work, which included the use of data on the prescribed task and filmed records of the real situation of the workplace in question, a need was identified for the design of a platform with adjustable height for the feet, providing adjustable space for workers of different anthropometric dimensions and giving them the choice of working while standing up or sitting, since working for long periods in the same position was considered an ergonomic risk factor to be eliminated.

After developing the theoretical representation of the problem, it was decided to use the anthropometric variables that would represent more than 90% of the people potentially working at the aforementioned workplace. The source of this data was an anthropometric survey conducted jointly by the Ministry of Science and Technology's National Institute of Technology, the Ergo&Ação Group and Embraer in 2001 (Menegon et al. 2002).

The validation of the system's representative model required an analysis of the main actors involved in the design. The necessary levels of detail and precision for the model were determined in this stage, enabling the beginning of the construction of the model in a virtual environment.

The virtual model was developed in two steps, beginning with the environment, using CAD software, followed by the human digital models, using the ***Jack 2.1*** modeling and human simulation software package belonging to UGS. Figure 2 illustrates the complete virtual model of the situation.

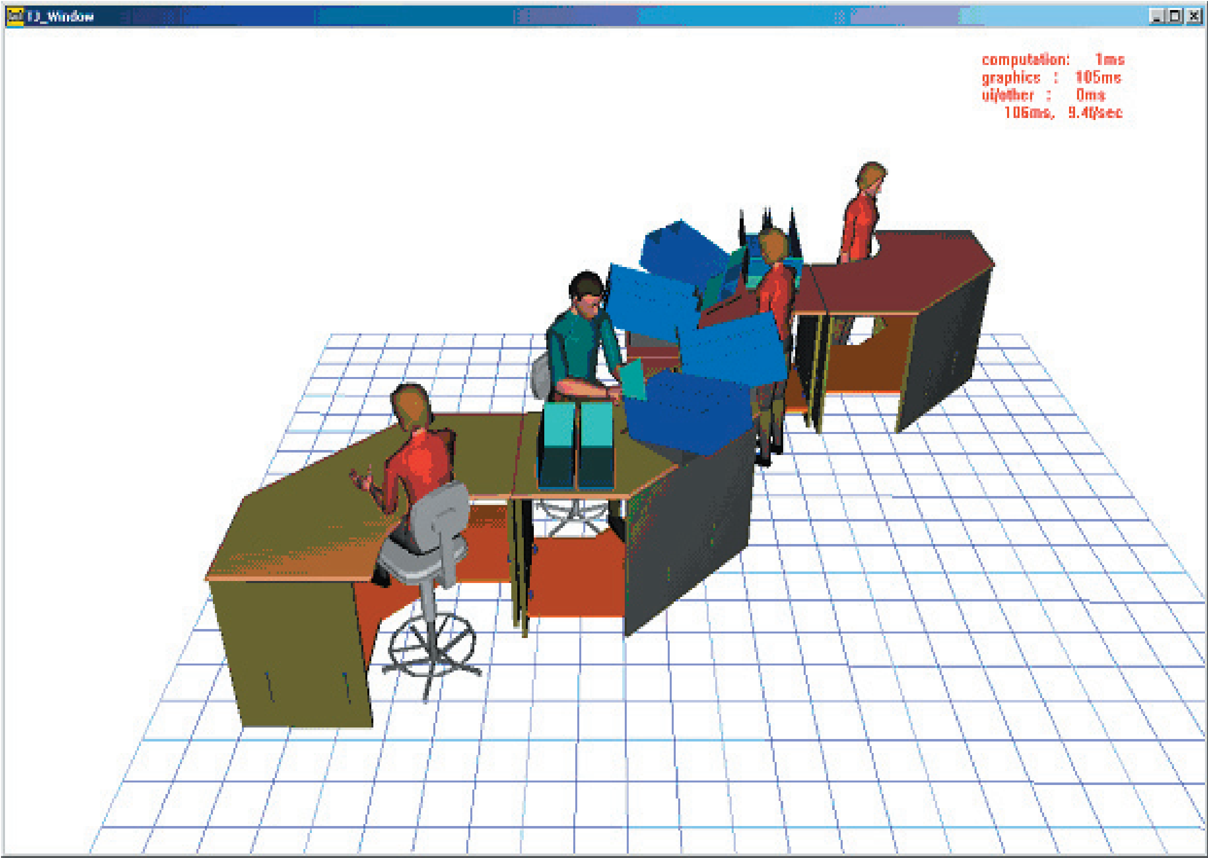

Figure 2. Virtual modeling of the packaging sector with the designed workplace

Using the computational tool, the use of the packaging table by a 5th percentile woman and a 50th percentile man (which, at the desired level of detail, can correspond to the 95th percentile female) was prototyped and simulated virtually. The choice of percentiles was due, among other factors, to the fact that in this work place there is strong tendency for the majority of the population to be female. This tendency can be verified in companies operating in different fields of endeavor where hand packaging tables are utilized.

The construction of the human digital models was developed starting from the input interface of the software's anthropometric data, which allow for the determination of 26 dimensional variables as well as the choice of male and female genders, as indicated in Figure 3, below.

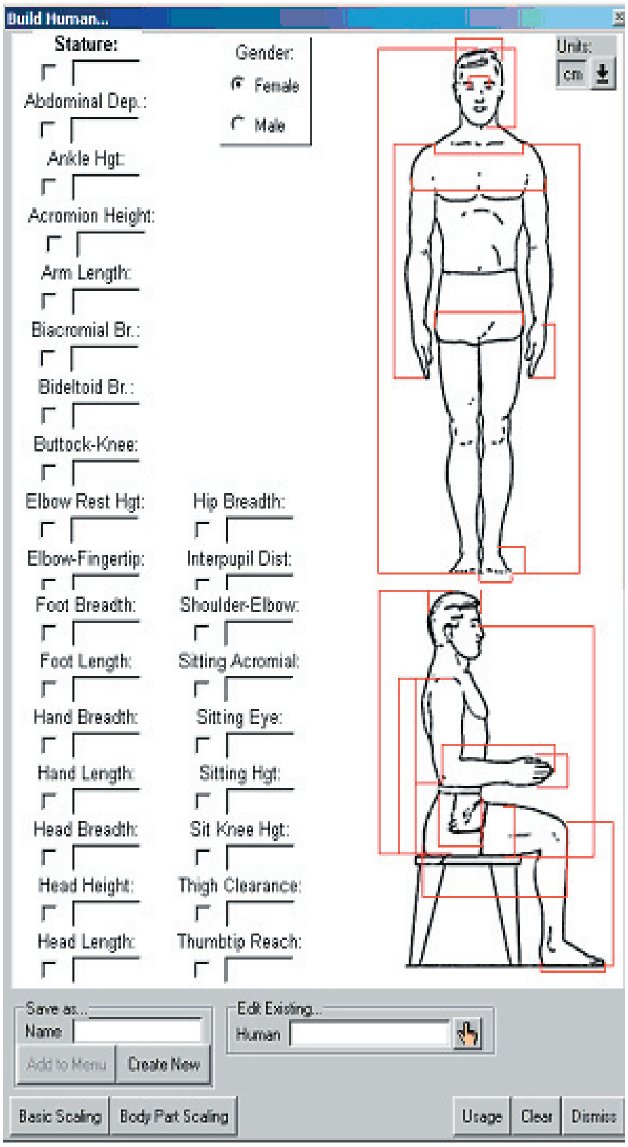

Figure 3. Interface for the construction of human digital models in the Jack 2.1 software program

For the proper use of the work plane in a sitting position, the use of a high chair was specified (a commercially available model), whose central column is adjustable from 640 to 740 mm, measured from the upper surface of the seat to the floor.

At this point, we were ready to begin the experimental phase with the model by means of human simulation, which considered the use of the chair at its minimum height (640 mm) for the male digital mannequin and at its the maximum height (740 mm) for the female mannequin. This allowed for an evaluation of the desired maximum and minimum variations in the height of the foot support.

Still in the experimental phase, a fixing system was designed to allow for easy adjustment of the platform.

After these stages, a result was reached for the probable future system, enabling some problems to be solved in advance.

4. Results

Overall, the results achieved through the use of human simulation were its help in communications among the different people involved in the design process, reduction of the design and validation time, and especially, the previous consideration of ergonomic factors in the process. The specific results of the use of the computational tool in this design process are listed in detail below:

– The minimum height of 150 mm in the adjustment of the foot platform was obtained by measuring the height from the floor to the soles of the male mannequin's feet, as depicted in Figures 4 and 5.

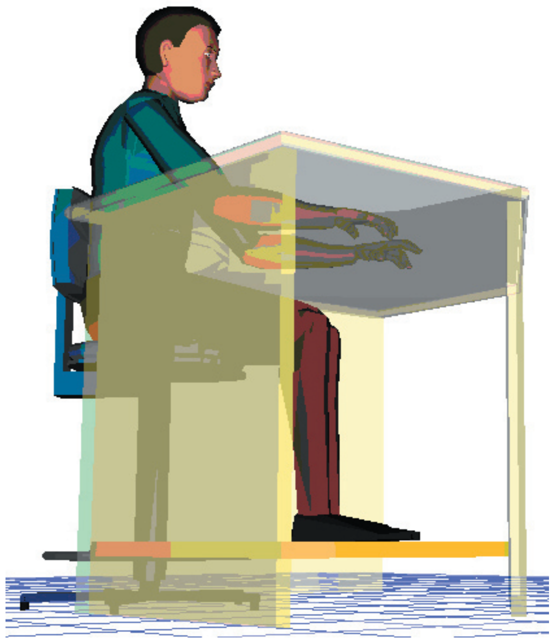

Figure 4. 50^{th} percentile male seated at the packaging table (side view)

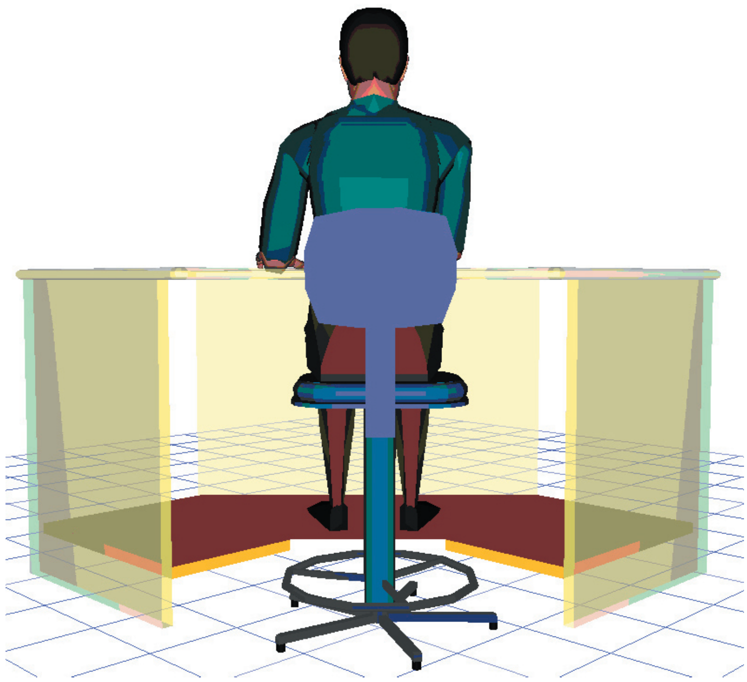

Figure 5. 50^{th} percentile male seated at the packaging table (back view)

– The maximum height of 350 mm of foot platform adjustment was obtained by measuring the height from the floor to the soles of the female model's feet, as depicted in Figures 6 and 7.

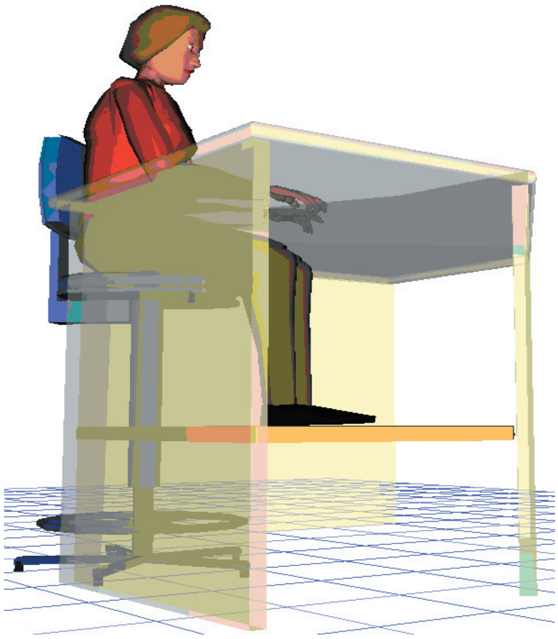

Figure 6. 5th percentile female seated at the packaging table (side view)

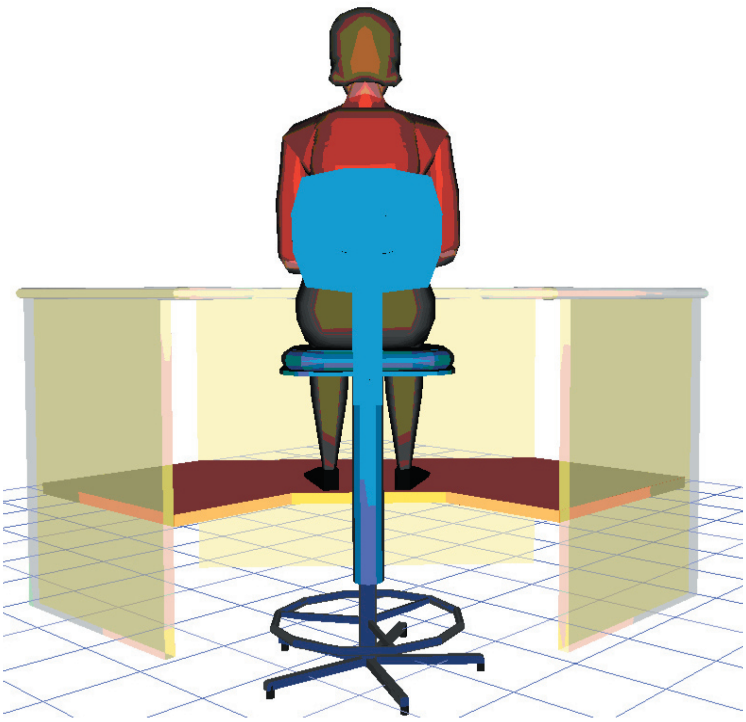

Figure 7. 5th percentile female seated at the packaging table (rear view)

– The adjustable platform was also designed to avoid collisions with the circular support of the specified chair, ensuring better conditions of usability; this detail is illustrated in Figure 3, shown earlier.

– For the easy and rapid adjustment of the platform's height, the use of a rapid blocking system was specified, as illustrated in Figure 8. This system requires no tools and can be handled at the workplace by the worker himself.

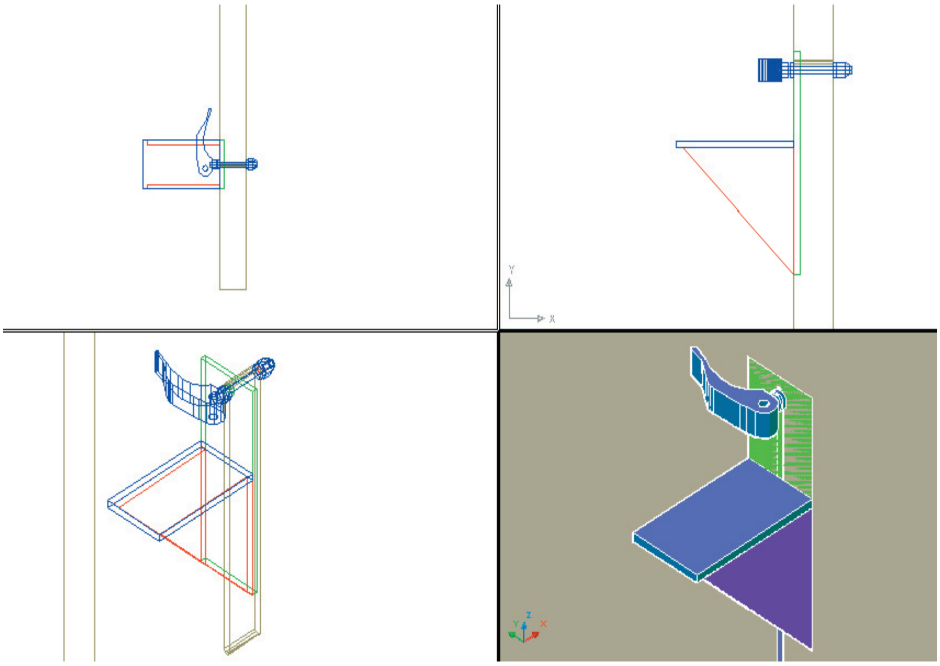

Figure 8. Rapid blocking fixing system

The results presented here demonstrate that the structured use of this technology can contribute to the activity of the designer and aid in decision-making, although it should be noted that the tool is unlikely to eliminate the need for physical prototyping, whose objective should be the real interaction of the designed object and its intended user (Figures 9 and 10).

Figure 9. Physical prototyping of the workplace

Figure 10. Physical prototyping in process of validation by workers

5. Conclusions

We conclude that the method employed in human simulation enables the designer to anticipate important details in workplace design, and that the computational tool used here displayed a good performance, insofar as it allowed for a conceptual evolution through the validation and testing of the proposed modifications.

However, it should be noted that the process of implementation should be monitored by the designer, who should inform the operators and their supervisors about the correct use of the end product. This can be done by means of a manual of good practices, a user's manual, and by training the users in the real work environment.

It can therefore be stated that simulation has contributed significantly to advances in the application of ergonomics in workplace design, but there are obvious risks in adopting a reductionist approach to this type of problem.

Cognition-related aspects and other social factors – variables that are difficult to observe and practically impossible to simulate – can strongly affect the end result. This statement is reinforced theoretically by the words of Castillo (Castillo, et al. 2005), who states, metaphorically, that in a chess game one perceives only the movement of the piece, which is evidently not the player's only activity, and by Dejours assertion (1997) that the real reveals itself only by the converse.

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