

The Role of Biomechanics and Psychophysics in Designing Hand Force Across Various Interfaces (An Analytical Study).

Lazhar Abdelmalek

¹ University of Shahid Hamma Lakhder El Oued (Algeria), Laboratoire Neuropsychologie Cognitive et Sociale

lazhar-abdelmalek@univ-eloued.dz

Receipt date : 12/04/2026 ; Acceptance Date: 24/05/2026

Abstract:

This research paper is about the importance of combining Biomechanics and Psychophysics when designing tools that people use, Biomechanics is the study of forces that affect the body and Psychophysics is the study of how people perceive sensory information, By combining these two fields we can design tools that're comfortable and efficient to use, which reduces physical strain and makes people feel safe and secure, This paper also talks about the challenges of designing tools that people use and presents ideas and recommendations based on these scientific principles, It emphasizes the role of technology in creating designs that're good for people and help them interact with their environment.

Keywords: Biomechanics, Psychophysics, Hand Force, Manual Interface Design.

* Lazhar Abdelmalek.

I – Introduction:

The study of how people interact with tools and devices is an important field that combines many different areas of study including Biomechanics and Psychophysics. Biomechanics is the study of movement and the forces that affect it while Psychophysics is the study of how people perceive sensory information. By combining these two fields we can better understand how people interact with tools and devices. This understanding helps us design tools that're comfortable, efficient and easy to use, which reduces physical and mental strain. This relationship is the foundation of performance and design and it drives the development of tools that enhance productivity, comfort, safety and security.

The design of tools and interfaces not improves how people perform tasks but also reduces the risk of injury and makes people feel more comfortable physically and mentally. However, how can we balance all these requirements while considering the diversity of people and the challenges of the environment? And what solutions can technology offer to ensure that designs are safe and sustainable?

What can technology do to make sure designs are safe and sustainable?

This paper looks at how to mix Biomechanics and Psychophysics to make designs that work well for people and improve how humans perform in different places. It also talks about the problems and possible solutions, in this area.

1-Importance and Objectives:

This paper aims to explore the role of Biomechanics and Psychophysics in improving the design of force. It provides a vision of how to achieve interactive designs that are safe, comfortable and efficient which enhances productivity while reducing physical and mental strain. Additionally, the paper highlights the challenges and proposed solutions for developing integrated interfaces and tools that meet human needs across various fields and domains.

2-The Concept of Biomechanics and Manual Force Analysis: Biomechanics is a part of science that looks at how forces affect living things how the human body moves and works. The main goal of biomechanics is to understand how muscles and bones and joints and ligaments all work together so that we can figure out how the human body is able to move.

Biomechanics is used in things like sports and medicine and physical rehabilitation to help people perform better and to help their bodies work better. This is really important for people who want to get better at sports or for people who need help getting their bodies to work properly again. Biomechanics helps us understand the body and how it moves, which is what makes it so useful, in these fields.

2.1. Manual Force Analysis:

Manual force analysis involves studying the forces generated during hand- activities focusing on measuring the magnitude, direction and distribution of these forces across muscular and skeletal structures. This analysis provides insight into movement patterns and the impact of these forces on body parts aiding in enhancing performance and minimizing risks and injuries associated with manual work or daily activities.

3-The Impact of Forces and Movements on the Human Body:

Forces whether external influence the human body by inducing changes in motion or altering tissue structure. For example:

3.1-External Forces:

Lifting objects is really bad, for your spine. It can cause injuries.

3.2- Improper Mechanical Movements:

Lifting things the way like bending too much or twisting is not good. It can hurt your muscles. Make them very tired.

3.3-Objectives of Analyzing Force Impacts:

- Objectives of Analyzing Force Impacts:
- Preventing injuries caused by strain.
- Improving movements and work performance.
- Developing rehabilitation strategies and assistive tools tailored to needs.

4-Applications of Biomechanics:

In Sports: Biomechanics enhances movement efficiency. Improves performance.

In Medicine: Biomechanics assists in diagnosing injuries and identifying treatment methods.

In Biomedical Engineering: Biomechanics contributes to the development of devices like prosthetics

5-Importance of Manual Force Analysis:

Manual force analysis is crucial for understanding how various forces affect the hands during activities, whether practical or athletic. This understanding offers benefits:

5.1- Reducing Occupational Injury Risks:

When we look at how people move, we can see what might cause them to get hurt on the job. This is called manual force analysis. It helps us find out what movements can lead to problems, like tendonitis or carpal tunnel syndrome. If we know what these movements are we can make the workplace better so that people do not get hurt from doing the tasks over and over. (Robertson & Caldwell, 2014).

5.2- Enhancing Functional Performance:

Understanding the distribution of forces during athletic tasks can improve movement coordination and efficiency. This in turn enhances performance in activities requiring specialized manual skills, such as writing or hand-intensive sports. (Winter, 2009).

5.3- Designing Customized Assistive Tools:

Accurate data from manual force analysis facilitates the creation of medical and industrial tools tailored to individual needs. These include devices or specialized professional tools that reduce hand strain and improve functionality. (Yu & Garrett, 2007).

5.4- Role in Rehabilitation:

Manual force analysis is a cornerstone of rehabilitation helping evaluate the body's response to treatment programs and enhancing their effectiveness. It is widely used to

monitor progress in patients recovering from hand or upper limb injuries. (Robertson & Caldwell, 2014).

5.5- Improving Performance:

In hand-intensive sports such as weightlifting or tennis manual force analysis refines movement techniques and boosts athletic performance. By studying force distribution during motions athletes can reduce injuries. Achieve better outcomes.

6- Applications of Biomechanics in Design:

Biomechanics is really helpful for making tools and equipment. This is because biomechanics helps us understand how forces affect the body. When we know how forces affect the body, we can make tools and technologies that help prevent injuries. This makes work environments safer and more efficient. Biomechanics also helps people perform better at their jobs no matter what field they are in. Biomechanics is about making things better and safer for people and that is why it is so important, for designing good tools and equipment.

6.1- Enhancing Work Tools:

In designing handheld tools such as screwdrivers or heavy industrial equipment force analysis ensures load distribution on the hands and joints. This reduces muscle and joint strain lowering the risk of injuries from stress (Hamill & Knutzen, 2015). Biomechanics also plays a role in improving office tools like mice and keyboards designing them to be ergonomic promote better posture and reduce muscle tension from prolonged use. (Winter, 2009).

6.2- Improving Industrial Designs:

Biomechanics aids in creating interfaces tailored to workers needs reducing fatigue and preventing injuries. For example, designing ergonomic control panels, displays or operating devices enhances productivity and reduces risk (Robertson & Caldwell, 2014). This analysis also contributes to optimizing machine and production line designs ensuring they are comfortable to use and aligned with capabilities.

6.3- Designing Medical Interfaces:

In the field Biomechanics informs the design of surgical tools and prosthetics to align with the body's natural movements. For instance, prosthetics are developed based on studies of natural limb motion ensuring comfort and effective mobility restoration. (Hamill & Knutzen, 2015). Surgical tools are also engineered using principles to enhance their efficiency and precision during operations improving surgical outcomes. (Nordin & Frankel, 2012).

6.4- Advancing Rehabilitation Tools:

Biomechanics contributes to the development of physiotherapy tools that assist patients in recovering from injuries. These tools are designed based on analyses of body movements and forces encountered during exercise ensuring they are safe and effective in accelerating recovery and enhancing outcomes (Yu & Garrett, 2007).

7- Psychophysics and Interaction with Interfaces:

Psychophysics is a part of psychology that looks at how things like light and sound and touch affect the way we see and interact with the world. This field is really, about figuring

out how our brain takes in all this information and turns it into things we can see and feel. The main goal of psychophysics is to understand how our brain works with all the information it gets and how this can help us make systems for people to use, like computers and other machines. Psychophysics is important because it helps us understand how people interact with things and how we can make these interactions better. By studying psychophysics, we can make things that're easier for people to use and that work better for them.

8-Relationship Between Physical Stimuli and Sensory Perception:

Physical stimuli are signals that we feel through our senses like light, sound or pressure. Our brain helps us understand these signals. We react to them in a certain way. This helps us make sense of the world around us.

For example:

* Light: When our eyes see light special cells in the eye called retinas take it in. They turn it into signals that our brain gets. Our brain then figures out that these signals are images or colors.

* Sound: Our ears pick up vibrations. These vibrations get turned into signals that our brain understands as sounds.

These physical stimuli really affect how we see things and use devices. For instance, if the light on a computer screen is too bright it can make it hard to read the text or be comfortable, for our eyes. Also, sound can greatly impact how easy it is to use a system.

9-The Role of Psychophysics in User Interface Design:

Psychophysics principles can be applied to enhance the user experience in interface design by:

9.1- Color Contrast:

Using appropriate color contrasts improves text readability. Reduces visual strain considering how the eye responds to light.

9.2- Tactile Interactions:

Touch-based devices utilize insights into how the skin responds to pain or pressure to refine the user interaction experience.

9.3- Auditory Interaction:

Voice-controlled systems work better when the sounds and frequencies are adjusted to match how our brain hears things. This makes it easier for us to talk to the system.

By using ideas from Psychophysics when we design displays and interfaces, we can make it easier for people to use technology. This is because the technology will work in a way that's similar to how our brain works. This makes using technology more comfortable, safer and more efficient. Voice-controlled systems and other technology are more efficient when they are designed with the user, in mind like this.

10- The Role of Psychophysics, in Interface Design:

User interface design is really important. Psychophysics plays a big role in it. This is because psychophysics helps us understand how people interact with machines. By studying how people see hear and feel things we can make user interfaces that're easy to use and feel natural.

Here is how psychophysics helps us design user interfaces:

10.1- Making Visual Interactions Better:

One way psychophysics helps us is by making sure the visuals on screens are clear and easy to see. This is done by choosing colors that're easy on the eyes and making sure there is enough contrast between the text and the background. For example, psychophysics helps us understand how people see colors and light which makes reading on screens comfortable.

Here is how psychophysics helps us design user interfaces:

10.1.1- Using Contrast and Colors:

Colors are picked carefully so that the text stands out from the background. This makes it easier to read whether you are using a phone or a computer. This is based on research by. (Gauthier & Shiffrar, 2001).

10.1.2- Layout of Visuals:

The space between text and pictures is balanced which helps guide the user's attention and makes it easier to navigate the interface. This means that psychophysics helps us understand how people see and understand visuals, which makes the user experience better.

10.2- Making Tactile Interactions:

Psychophysics also helps us make interactions that involve touch more enjoyable. By studying how the skin feels pressure and touch we can make responses that feel natural. This is especially important for technology, where psychophysics helps us design systems that respond well to touch.

10.2.1-Using Haptic Feedback:

Vibrations or other tactile effects are used to give users feedback when they press buttons or swipe screens. This feedback tells users that their actions have been registered, which is based on research (Norman, 2013).

10.3- Making Auditory Interactions:

Psychophysics has also helped improve interactions that involve sound. For example, in voice assistants' sounds are designed to match how the brain processes sound. This means that psychophysics helps us understand how people hear and understand sound which makes the user experience better.

10.3.1- Optimizing Sound Frequencies:

Sounds are made clear so people can easily understand them. This makes it better when we talk to machines. They talk back, to us. The study of psychophysics is really helpful when we design user interfaces for people to use. It is an example of how psychophysics helps us make user interfaces that are easy to use and understand.

10.3.2- Combining Auditory and Tactile Interactions:

Systems that use both sound and touch help people interact with devices in a way. This is one example of how psychophysics helps us create better user interfaces.

We can design devices that're easy to use when we combine sound and touch.

This combination also makes it comfortable for users to interact with devices.

Psychophysics plays a role in designing user interfaces.

It helps us understand how people perceive and respond to stimuli.

By using sound and touch we can create devices that are easy and comfortable to use.

10.4- Responding to Hand Gestures:

Psychophysics is really useful for designing interactions that involve hand gestures like tapping or swiping on touchscreens. We can figure out how people use their hands and what happens when they touch things. This helps us make these interactions on touchscreens work well and feel natural. Psychophysics helps us make sure that when people tap or swipe, on touchscreens it does what they want it to do. (Goldstein, 2014).

10.5- Understanding Spatial Perception and Navigation:

Psychophysics is really useful when we are designing interfaces. We want people to be able to find their way easily.

To do this we need to know how people see distances and how things are laid out in space.

When we understand these things, we can make navigation very easy.

This is because psychophysics helps us understand how people see space and how they understand it which makes the experience of using something better for the user.

Psychophysics is about figuring out how people see and understand space and that is what makes psychophysics so important, for designing good interfaces.

10.5.1- Spatial Orientation:

Menus and elements are organized to make navigation easy giving users a sense of movement on the screen. This is an example of how psychophysics helps us design user interfaces.

10.5.2 Smooth Navigation:

Applications that let people move easily between screens or options by swiping or scrolling make the experience more fun for the user. This is another way that psychophysics helps us make user interfaces better.

In terms psychophysics is important, for making user interfaces better. When designers use the ideas of psychophysics, they can make systems that're easy to use and feel natural.

The reason is that psychophysics helps us understand how people use machines, which makes the experience of using them for the user. By using psychophysics designers can create user interfaces that're comfortable and easy to navigate which is what makes the user experience of psychophysics so good.

11- The Connection Between Biomechanics and Psychophysics in Design:

The combination of biomechanics and psychophysics is important for designing products. Each field contributes to improving interaction with tools and environments through innovative solutions. Biomechanics studies the forces and movements that affect the body while psychophysics looks at how the brain processes sensory information. When these

fields are combined, products and interfaces become more comfortable, safe and efficient for users.

11.1- Interaction Between Humans and Their Environment:

Biomechanics focuses on how movements and forces affect the body like the impact on muscles and joints during motion or work. This understanding helps design tools and devices that align with movement reducing injuries and enhancing comfort. On the hand psychophysics examines how the brain responds to stimuli like light, sound and touch. Insights from this field enable the creation of interfaces that interact comfortably with the eyes (McLeod, 2018).

By merging these two fields' designers can develop devices and tools that minimize both physical and mental stress. For instance, biomechanics can guide how pressure impacts the hands and arms during tool use while psychophysics can refine users' perception of auditory stimuli associated with those tools.

11.2- Enhancing User Experience Through Shared Principles:

11.2.1- Designing Tools:

For tools like screwdrivers biomechanics determines the optimal way to distribute force across the hand and wrist reducing physical strain. Meanwhile psychophysics influences the choice of shapes and colors ensuring the tool is visually intuitive and easy to use.

11.2.2- Tactile Interaction:

In touch-based devices like tablets or smartphones the integration of biomechanics and psychophysics improves user comfort. By considering how physical movements, such as pressing or swiping affect the user designers can create screens and devices that respond naturally simplifying human-machine interaction.

11.2.3- Auditory Interaction:

When designing sound-based systems like voice assistant's psychophysics ensures that sound frequencies are clear and easy to understand. Simultaneously biomechanics contributes to creating devices that accurately capture sound while accommodating the user's body movements.

11.2.4- Touch and Vibrations:

In devices with feedback, such as smartphones biomechanics determines the level of pressure the body can comfortably tolerate. Psychophysics fine-tunes vibrations to elicit the desired user response ensuring an interaction experience.

11.3- Navigation and Spatial Perception:

11.3.1- Biomechanics: This field examines how the body moves within a space or workspace. Understanding motion allows for designing interfaces that facilitate smooth navigation.

11.3.2- Psychophysics: Psychophysics enhances the brain's ability to perceive distances and spatial relationships between elements. This knowledge can be applied to design interfaces that enable users to navigate between options or pages using gestures improving interaction with the system.

In summary the integration of biomechanics and psychophysics in design is essential for creating efficient and comfortable interactive experiences. By combining insights about body movements with perception designers can develop tools and products that reduce physical and mental fatigue making interactions with technology smoother and more natural.

12- Challenges and Solutions in Manual Interface Design:

Designing manual interfaces is a big challenge that requires a deep understanding of user needs and physical characteristics. The goal is not just to make something that works but to make sure it is comfortable and effective to use. Designers face obstacles from physical strain to designs that do not fit the user's needs. However, with innovation and the integration of knowledge effective solutions can create smooth and comfortable user experiences.

12.1- Physical Strain from Prolonged Use:

- Using tools for a long time can lead to muscle and joint fatigue especially if the tools are not designed to distribute forces evenly. For example, tools that require a grip can cause discomfort in the hand or wrist.
- Solution: Use principles to design ergonomic handles and cylinders that fit the hand naturally. Lightweight and flexible materials can reduce strain while adjustable designs ensure comfort for extended use.

12.2- Difficulty in Interaction Due to Inappropriate Size or Shape:

- Sometimes manual tools can be uncomfortable because of their size, which may not fit the user's hand making them hard to control or use.
- Solution: Create tools that adapt to hand sizes considering the diversity of human hands. Designed tools enable users to interact with ease and precision enhancing the overall experience as seen in research by (Robertson & Caldwell, 2014).

12.3- Complexes Interaction:

Complex interaction methods can make tools hard to use effectively. Touch- or motion-based commands may be unclear or imprecise complicating the process.

Solution: Improve responsiveness to commands by incorporating motion feedback. For instance, adding vibrations or visual signals provides users with feedback simplifying decision-making and tool interaction.

12.4- Interaction in Work Environments:

Many manual tools are used in different environments, such as workshops or hospitals where users must interact with tools in uncomfortable positions or angles.

Solution: Design flexible tools that adapt to the user's posture. For example, handles that rotate or tools designed for use in positions can reduce physical strain in varied work settings.

12.5- Poor Responsiveness to Physical Stimuli:

- Some manual interfaces lack sensitivity to respond to fine pressures or movements making it challenging to execute commands accurately.
- Solution: Employ advanced sensing technologies, such as motion-sensitive devices ensuring precise and immediate responses. Integrating these with feedback provides clear tool responses aiding users in gauging interaction levels.

12.6-Weak Tactile Feedback:

- When using tools that rely on sensations users may experience discomfort or a lack of appropriate feedback, such as vibrations or tangible changes during interaction.
- Solution: Enhance tactile feedback through materials like flexible components or embedded sensors that provide users with a tangible response. (Hall, 2019).

The challenges in designing interfaces lie in achieving a balance between comfort and efficiency. However, using principles from biomechanics and psychophysics can drive solutions that improve user experiences. By designing tools and devices that account for hand comfort and balanced force distribution users can interact with tools smoothly and effectively reducing physical fatigue and boosting productivity.

Conclusion:

Combining biomechanics and psychophysics in interface design is crucial for enhancing user experience and creating more comfortable and efficient interactive environments. Biomechanics helps us understand the impact of forces and movements on the body while psychophysics offers insights into how the brain perceives sensory stimuli like sound, light and touch. This integration leads to tools that not improve functional performance but also enhance user comfort and reduce physical and mental strain.

The future of design heavily depends on merging these fields to develop tools and products that respond better to human needs making humans the focal point of interactive environments. Future designs should prioritize sustainability in making tools comfortable and safe for long-term use while improving performance in diverse settings.

To conclude technology is a factor in realizing these visions offering limitless opportunities to develop innovative solutions that address human needs and create interactive environments that enhance human performance. Continuous research and development efforts in this field are essential to delivering user-friendly designs that place users at the centre improving quality of life and well-being in a world increasingly reliant, on technology.

IV-References bibliographiques:

1. Hamill, J. And Knutzen K. M. (2015) The book is called basis of human movement and it is the 4th edition. It was published by Lippincott Williams & Wilkins. p 19 to 17.
2. Winter, D. A. (2009) The book is called Biomechanics and motor control of movement and it is also the 4th edition. It was published by Wiley. p 100 to 107.

3. Gauthier, G. M. And Shiffrar M (2001) the psychology of perception. It was published by McGraw Hill .2001. p 155 to 160.
4. Goldstein, E. B. (2014) Sensation and perception. It is the 9th edition. It was published by Wadsworth Cengage Learning in. p 136 to 137.
5. Norman, D. A. (2013) the design of things. It was published by Basic Books. p 200 to 207.
6. Gibson J. J wrote. (1979) the approach to visual perception. It was published by Houghton Mifflin. p 201 to 202.
7. Nordin, M. And Frankel V. H. (2012). Basic biomechanics of the system. It is the edition. It was published by Lippincott Williams & Wilkins. p 19 to 20.
8. Robertson, D. G. E. And Caldwell G. E. (2014) Biomechanics of the body. It was published by Routledge. p 65 to 67.
9. Yu, B. And Garrett W. E (2007). The Oxford textbook of sports medicine. The chapter is called Biomechanics of the extremity and injury mechanisms. It was published by Oxford University Press. p 190 to 197.
10. Hall S. J. (2019). biomechanics and it is the 8th edition. It was published by McGraw-Hill E. p 80 to 83.