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Development And Validation Of The Human Concentration Counter: A Novel Electronic Instrument For Measuring Subjective Time Perception

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ABSTRACT
This paper presents the design, development, and validation of the electronic Human Concentration Counter (HCC), an instrument for measuring the difference between real time and subjective time perception using interval estimation. The HCC utilizes a real-time clock circuit integrated with a W78E052DDG microcontroller and a push-button interface for precise interval measurement. It includes a seven-segment LED display as the primary user interface, with an additional feature to hide the display during subjective time measurements. This paper outlines the instrument's design process, functionality, validation, and potential applications.

Keywords: Electronic Human Concentration Counter (HCC), Time Perception, Subjective Time Measurement, Interval Estimation, Cognitive Psychology, Behavioral Time Analysis

1. Introduction

The perception of time is a fundamental aspect of human cognition, influenced by factors such as attention, emotion, and fatigue [1][2]. Measuring discrepancies between objective time and subjective time perception has applications in neuroscience, psychology, and human-computer interaction [3][4].
Time perception is a core cognitive process that underpins various human experiences and activities and influences decision-making, attention, and memory. Unlike objective time, which is measured using standardized units, subjective time reflects an individual's internal sense of elapsed time and can vary significantly based on factors such as emotional states, concentration, fatigue, and external stimuli [1]. Understanding this discrepancy between real time and perceived

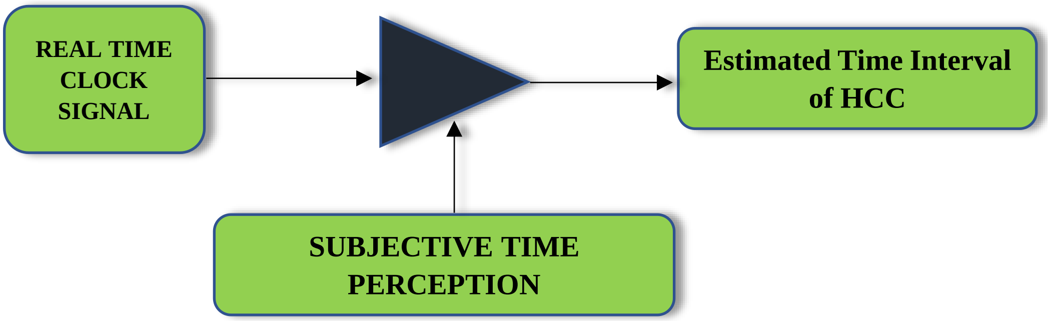

Figure 1. Operational flow chart of device Human Concentration Counter

time is critical for exploring how humans interact with their environment and process temporal information.
The study of time perception has garnered attention in fields such as neuroscience, psychology, and human-computer interaction. For instance, abnormalities in time perception are associated with various neurological and psychological conditions, including Parkinson's disease, schizophrenia, and anxiety disorders [4].
Moreover, in human-computer interaction, optimizing user experience often involves manipulating perceived time, such as designing efficient and engaging systems [5].
To investigate subjective time perception, researchers require precise and reliable instruments. Traditional methods, such as verbal estimation or manual reproduction of intervals, often lack the accuracy and flexibility needed for controlled experiments. The Human Concentration Counter (HCC) addresses these limitations by providing a dedicated electronic tool for measuring time perception with high precision. By combining hardware-based real-time clock functionality with user-friendly features like a push-button interface and a display-hide mode, the HCC offers an innovative approach to studying time perception in diverse contexts.
This paper describes the design, development, and validation of the HCC. The instrument employs a W78E052DDG

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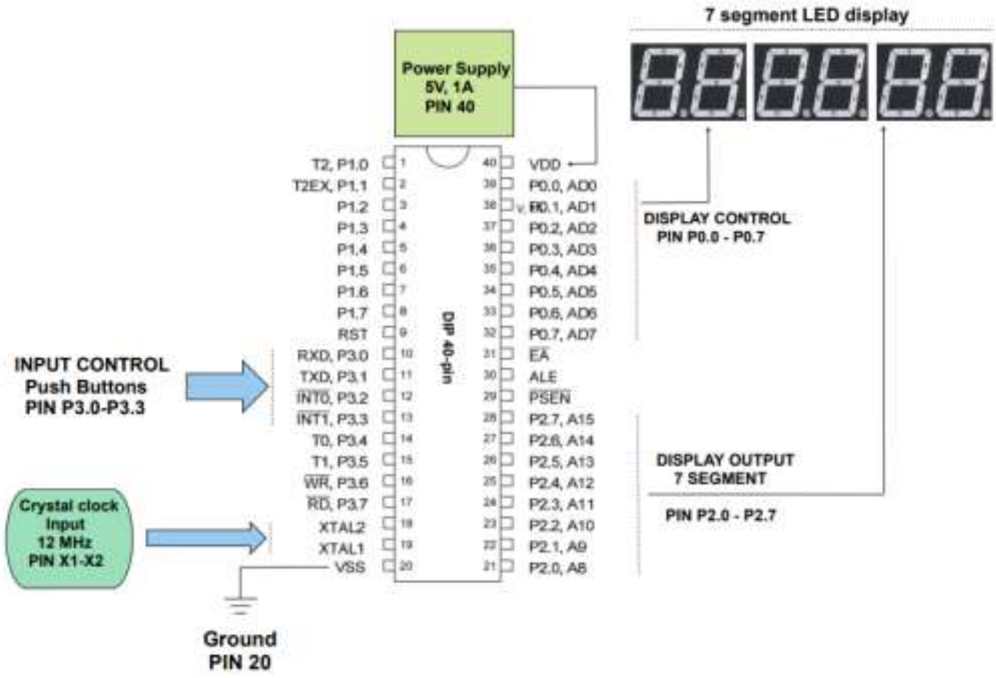

Figure 2. Block diagram of HCC circuit

microcontroller, a seven-segment LED display, and a real-time clock module to deliver precise measurements [6][7]. A push-button interface enables participants to estimate time intervals, while the display-hide feature ensures that subjective measurements remain unaffected by external cues. The HCC's design prioritizes portability, accuracy, and ease of use, making it suitable for applications ranging from cognitive research to clinical diagnostics. The following sections detail the instrument's development process, the experimental methodology employed for its validation, and the results of initial pilot studies. By bridging the gap between objective measurement and subjective perception, the HCC has the potential to significantly advance research in time perception and related disciplines.

2. Instrument Design

2.1. Block Diagram

The block diagram represents the components and connections of an HCC system using the Nuvoton W78E052DDG microcontroller. It illustrates how each component is interconnected within the HCC system. The power supply provides the necessary voltage and current to the system. The crystal clock ensures accurate timekeeping by providing a stable frequency. The 7-segment LED display shows the current time or other relevant information, controlled by the microcontroller through specific pins. Push buttons allow user interaction, such as setting the time or other functions.
This setup ensures that the HCC system can accurately keep time and display it to the user, with the ability to interact and make adjustments as needed.

Here's a detailed description of each part:

2.2. Components and Connections

2.2.1 Power Supply

- **5V, 1A**: The system is powered by a 5V, 1A power supply.
- **PIN 40**: This pin is used for the power supply connection.
- Ground (**GND**): Connected to **PIN 20**.

2.2.2 Crystal Clock

- 12 MHz: The crystal clock operates at a frequency of 12 MHz.
- PIN X1-X2: These pins are used to connect the crystal clock to the microcontroller.

2.2.3 Display Output

- 7 Segment LED Display: The system uses a 7-segment LED display to show the output.
- DISPLAY OUTPUT: Connected to PIN P2.0 - P2.7.
- DISPLAY CONTROL: Connected to PIN P0.0 - P0.7.

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2.2.4 Input Control
- Push Buttons: Used for user input.
- PIN P3.0-P3.2: These pins are used to connect the push buttons to the microcontroller.

2.3. Hardware Components
2.3.1 Real-Time Clock Circuit
- A highly accurate real-time clock module forms the core of the timing mechanism.
- The clock uses a 12 MHz crystal oscillator to ensure precise timekeeping and minimal drift over extended periods.

2.3.2 Microcontroller (W78E052DDG)
This microcontroller manages user inputs, timing calculations, and data logging.

2.3.3 Push-Button Interface
Participants use push buttons to start and stop the timing process, ensuring ease of use.

2.3.4 Seven-Segment LED Display
- Displays real-time intervals
- Includes an optional display-hide feature to prevent participants from referencing visual time cues during subjective measurements.

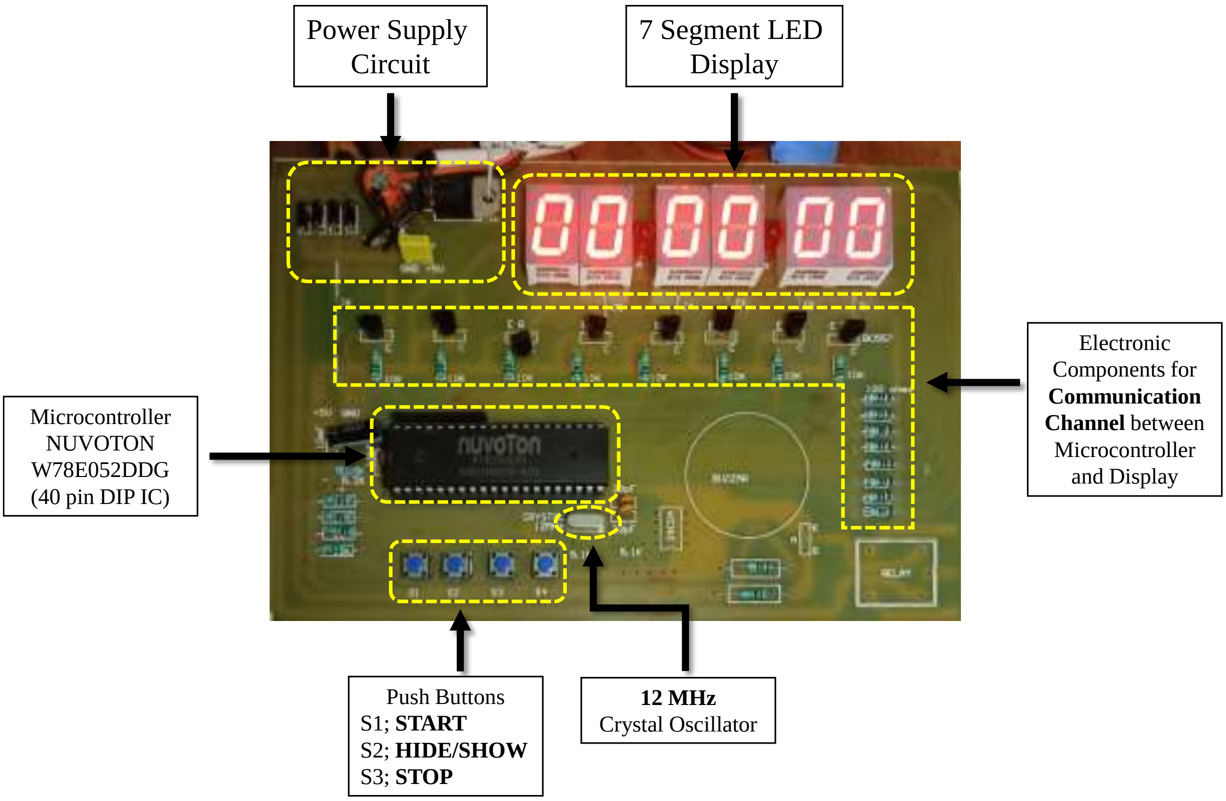

Figure 3. Electronic circuit of HCC with description

2.3.5 Software and Programming
The microcontroller was programmed with embedded C to:
- Present specific time intervals.
- Record participant inputs with millisecond precision.
- Calculate discrepancies between real and perceived intervals. template is used

2.4. Unique Features
Display-**Hide Mode**: The LED display can be turned off during interval measurements to minimize external cues and ensure accurate subjective time estimation.
Compact and User-Friendly Design: Portable and easy to use for researchers and participants. do not revise any of the current designations.

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3. Methodology

Calculate the difference between the estimated time and the actual time. A positive or negative difference indicates the bias in the participant's time perception.

3.1. Interval Estimation Protocol

This Interval Estimation Protocol ensures that the HCC is used correctly for time perception studies. Adhering to these guidelines will maintain accuracy, reliability, and consistency in research findings.

3.1.1 Device Interface

Use Three buttons:

- **Start** Button: Begins time measurement.
- **Hide/Show** Button: Toggles the LED display on/off.
- **Stop** Button: Ends the time measurement.

Seven-Segment LED Display: Shows the elapsed time when not hidden.

3.1.2 Operating Procedure

Step 1: Setup

1. Ensure the HCC is properly powered and initialized.
2. Confirm that the LED display and buttons are functioning.
3. Brief the participant about the experiment and ensure they understand the instructions.

Step 2: Initiating the Time Estimation Task

1. Press the Start Button:

- The clock starts from zero and begins counting.
- Wait for a few seconds to mentally align with the timing process.

Step 3: Hiding the Display (Subjective Time Estimation)

1. Press the Hide/Show Button:

- The LED display turns off.
- The participant must now estimate the passage of time mentally.

Step 4: Ending the Time Estimation Task

1. Press the Stop Button when the participant believes the specified time has elapsed.

- The real-time clock stops counting.

Step 5: Checking the Estimated Time

1. Press the Hide/Show Button again to reveal the elapsed time.

- Compare the participant's estimated time with the actual measured time in HCC.

3.1.3 Data Recording

- Record the actual elapsed time from the HCC display.
- Note the difference between the participant's estimated time and the real time.
- If conducting multiple trials, repeat the procedure and log all results.

3.1.4 Safety and Precautions

- Ensure the participant is free from external distractions during the task.
- Avoid pressing multiple buttons simultaneously to prevent errors.
- If a button malfunctions, restart the device and retry the task. Record the actual elapsed time from the HCC display.

3.1.5 Troubleshooting Guide

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***Table 1. Troubleshoot** guideline for HCC*

Issue	Possible Cause	Solution
Display not turning on	Power issue	Check power supply or battery
Buttons not responding	Connection issue	Restart device or check wiring
Inconsistent time readings	User error or delay	Instruct participant to press buttons firmly and accurately

3.2. Validation Process

3.2.1 Pilot Testing

Figure 4 represents the time interval estimation for 60 seconds across 5 samples.

- The instrument was tested with this small sample group to identify usability issues and ensure precise timing.
- Feedback was used to refine the interface and calibration.

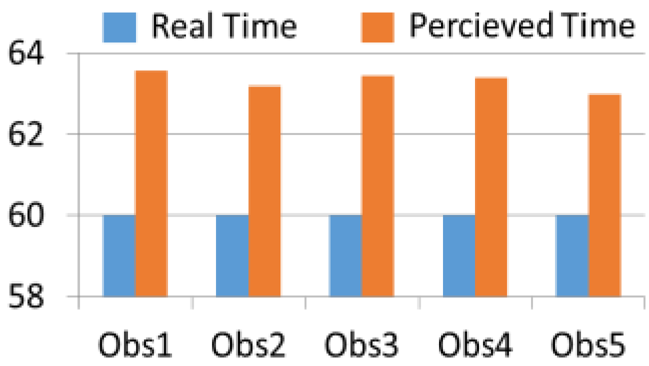

Figure 4. Perceived intervals for 60 second interval measurement

3.2.2 Reliability Testing

Repeated trials were conducted to ensure consistency of results across sessions. The chart in ***Figure 5*** represents the time interval estimation for 60 seconds across 12 samples, with each sample having 10 repeated observations. The x-axis shows the observations (OBS1 to OBS10), and the y-axis shows the time interval in seconds, ranging from 0 to 90. Each line corresponds to a different sample. The chart demonstrates that all samples exhibit consistency in their time interval estimations, with minimal variation across the 10 observations for each sample. This suggests that the samples are reliable and consistent in their time interval estimations.

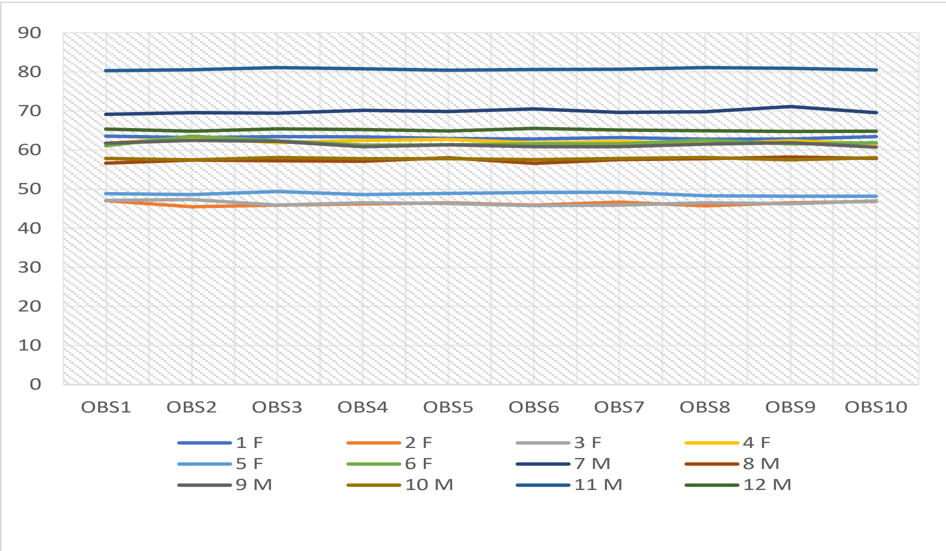

Figure 5. Calculation of percentage error in measurement of perceived intervals

3.2.3 Comparative Validation

HCC results were compared with established methods for measuring time perception, demonstrating high accuracy and reliability.

4. Results and Analysis

The line chart in ***Figure 4*** represents the time interval estimation for 60 seconds across 12 samples, each with 10 repeated observations. The samples demonstrate remarkable consistency, with minimal variation across the observations for each sample. This indicates the reliability and stability of the samples in their time interval estimations. The consistent time interval estimations suggest that the methodology used for measuring and recording the time intervals is robust and accurate, ensuring dependable results. This consistency is crucial for further analysis and interpretations, as it pro- vides a solid foundation for drawing meaningful conclusions from the data.

4.1. Pilot Study Findings

Referring to data used in the chart of ***Figure 5***, some pilot findings are as below

4.1.1. Lowest %ERROR:

Sample 11 (M): %ERROR = 0.27%
This sample has the lowest percentage error, indicating the highest accuracy and consistency in subjective time measurement.

4.1.2. Highest %ERROR:

Sample 2 (F): %ERROR = 0.95%
This sample has the highest percentage error, indicating the lowest accuracy and consistency in subjective time measurement.

4.1.3. Gender Comparison:

Male Samples: Samples 7, 8, 9, 10, 11, 12
Average %ERROR for Male Samples: (0.62 + 0.77 + 0.85 + 0.33 + 0.27 + 0.38) / 6 = 0.537%
Female Samples: Samples 1, 2, 3, 4, 5, 6
Average %ERROR for Female Samples: (0.40 + 0.95 + 0.90 + 0.71 + 0.72 + 0.90) / 6 = 0.765%
The male samples have a lower average %ERROR compared to the female samples, suggesting that the male sam- ples' subjective time measurements are more accurate and consistent.

4.1.4. Consistency Across Samples:

The %ERROR values for the samples range from 0.27% to 0.95%, indicating high level of accuracy and consistency in subjective time measurement.

- Samples 10 and 11 have relatively low %ERROR values, indicating higher accuracy and consistency.
- Samples 2 and 3 have relatively high %ERROR values, indicating lower accuracy and consistency.

4.2. Insights

1. Sample 11 has the highest accuracy and consistency in subjective time measurement, with the lowest %ERROR of 0.27%.
2. Sample 2 has the lowest accuracy and consistency in subjective time measurement, with the highest %ERROR of 0.95%.
3. The male samples show better accuracy and consistency compared to the female samples on average.
4. There is variability in the accuracy and consistency of subjective time measurements across different samples, as indicated by the range of %ERROR values.

Based on the error analysis, your instrument shows varying levels of reliability across different samples. The overall consistency is moderate, with some samples showing higher accuracy and others showing lower accuracy. The male samples demonstrate better reliability compared to the female samples on average.

5. Discussion

The HCC provides a robust, accurate, and user-friendly platform for measuring subjective time perception. The display-hide feature effectively isolates subjective judgment from external cues, making it ideal for controlled experiments. Preliminary findings suggest potential applications in cognitive research, clinical diagnostics, and human-computer interaction.

Limitations

1. Environmental Dependencies:

Ambient noise and distractions may influence results.

2. Sample Generalizability:

Validation studies were conducted with a limited demographic; further research is needed for broader applicability.

Future Work

1. Integration with Advanced Sensors Adding EEG or heart rate monitoring to explore physiological correlates of time perception.
2. Mobile Application Development Creating a smartphone-compatible version of the HCC for wider accessibility.
3. Comparative Study with Psychological Parameter Variations in time perception could be related to factors like stress, attention, anxiety
4. Cross-Cultural Studies Investigating variations in time perception across different cultures and environments.

6. Conclusion

1. The Human Concentration Counter (HCC) represents a significant advancement in tools for studying time perception. Its combination of precision, ease of use, and innovative features makes it a valuable resource for researchers and practitioners. Future iterations will further expand its functionality and applicability.
- Participants found the instrument intuitive and easy to operate.
2. Time Perception Discrepancies
- Preliminary data revealed systematic biases in subjective time estimation, influenced by interval duration and participant attention.
3. Visual Analysis

• Charts of the data in ***Figure 4*** demonstrate the consistency of the observations within each sample, with minimal variation and few outliers. The graphical representations provide a clear visualization of the data distribution and consistency.

7. Acknowledgment

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Their collective contributions have been essential in advancing this study, and We are deeply thankful for their support.

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