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Wearables, IoT, and Big Data: The new revolution in cognitive science

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A new revolution in cognitive science is now possible thanks to portable devices enabled to measure physiological variables non-intrusively, the Internet of Things that allows information to be collected and stored in real time from different locations, and big data techniques for identifying patterns that can be used to make decisions, predict behavior or create machine learning and artificial intelligence models. Research supported by these technologies will provide valuable insights into the impact that environmental circumstances have on the cognitive processes involved in different tasks, and how this can be detected through biological markers.

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The research on cognitive science has been boosted in recent decades by the development of neuroscientific techniques that allow recording the physiological activity of the brain (e.g., functional magnetic resonance) and the peripheral nervous system (e.g., pupillary diameter). Until recently, the use of this type of techniques has been restricted to the laboratory setting, due to the bulk of the equipment required for it. This supposes a limitation regarding the possibility of generalizing the results to real life contexts. Currently, available resources allow this research to be extended to more ecological scenarios. Importantly, many of these resources are smart devices with embedded sensors, microchips, and specific software that can connect to the internet for the purpose of exchanging data with minimal human intervention, what we know as the Internet of Things (IoT). These web-enabled devices can be all kinds of objects: smart watches, electronic tattoos, refrigerators, air-quality sensors, traffic lights, drones, or large-scale industrial machinery. In addition,

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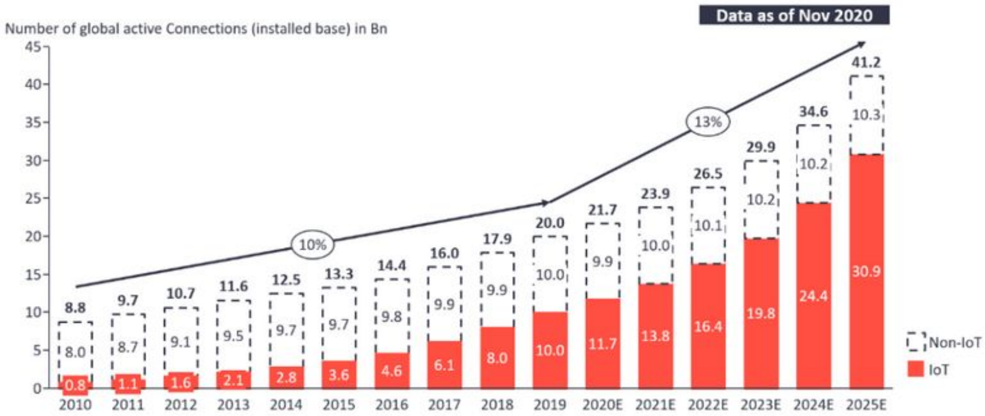

Figure 1. Forecast of the number of IoT and Non-IoT device connections. Source: IoT Analytics – Cellular IoT & LPWA Connectivity Market Tracker 2010-25 (https://iot-analytics.com/state-of-the-iot-2020-12-billion-iot-connections-surpassing-non-iot-for-the-first-time/).

to manage and analyze the immense amount of data generated by the IoT, complex big data analysis procedures have been developed. The purpose of big data analysis is to identify trends and patterns that can be used to make decisions, predict behaviors, or create machine learning and artificial intelligence models.

The applications of IoT are virtually limitless in very varied fields such as industry, health care, education, or urban planning. Although the potential of these technologies in cognitive science research is yet to be exploited, their usefulness is obvious. Firstly, there are sophisticated wearable devices such as smart watches, that can measure different physiological parameters (e.g., heart rate, skin conductivity, body temperature) in situ and in a non-intrusive way. Research studies in this area are scarce, but there is some evidence on the reliability of physiological metrics obtained with wearable devices for the assessment of different psychological variables (for a recent systematic review see Hickey et al., 2021). In addition, these wearables can pair with other devices, such as smart phones, via wireless networks, and connect to a cloud service for storing large amounts of data from different locations (Figure 1). Subsequently, this big data can be analyzed to infer the cognitive processes involved in real-life situations. For example, we could assess real-time fluctuations in sustained attention, mental workload, cognitive fatigue, or stress, during the performance of learning tasks in school, driving vehicles, or operating safety-critical systems.

Research on the cognitive processes of driving is possibly one of the areas where these technologies could be most fruitful. A driver monitoring platform can be developed with car sensors to collect real-time information on vehicle and driving behavior (e.g., eye movements, steering wheel movements pattern, driving errors such as deviations from the route), along with wearable body sensors to collect biometric data from the driver (Dehzangi & Williams, 2015). This information could be analyzed in combination with real-time data about atmospheric conditions, traffic jams, road works and other contextual circumstances that could affect driving—obtained from variable information panels, weather applications, or navigation apps like Google Maps. The Dirección General de Tráfico [Central Traffic Headquarters] in Spain has been working for years on the project of a platform that uses 5G technology to keep all road users connected in real time, offering them information on everything that is happening on the road (Gutiérrez, 2021). This kind of platform can also offer very useful information for research purposes.

Another area where these technologies have enormous potential is the evaluation and design of human-centered environments. For example, Li et al. (2022) have developed a process for evaluating the affective quality of urban public spaces based on multiple physiological signals (EDA, ECG, and EMG). In their experiment 20 participants walked through different urban spaces (campus public spaces, residential areas, park spaces, memorial spaces, and historical pedestrian street spaces) wearing a portable physiological signal feedback instrument and a GPS to record the participants' location information simultaneously. Immediately after walking through each space, participants also filled out a questionnaire to obtain self-reported emotional information. The data collected was used to train and test models for classifying the quality of urban spaces. The obtained classification accuracy was 92.59% for binary models (positive-negative) and 91.07% for ternary models (positive-neutral-negative).

In short, we have research that supports the reliability of the physiological measurements taken with wearable devices, as well as the validity of cognitive variable prediction models based on the analysis of these biometric data. As far as we know, there is still a further step to be taken using these methodologies: to obtain data from real situations and analyze them together with those from other IoT devices (e.g. sensors placed in cars, cities or smart buildings) through big data analysis techniques. The results will have multiple and important applications such as the implementation of safety systems for the prevention of accidents or the design of human-friendly environments.

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