# Summary of NO-STRESS Manufacturing thesis

Stress occurs when demands from the external environment exceed an individual's ability to cope with them effectively (Lazarus, 1966). Work-related stress can cause errors or accidents at work (Wegner, 1988) and lead to physical and psychological consequences for workers (Han et al., 2017), decreasing productivity and increasing costs for companies.

In Manufacturing, the relevance of this issue grew over the last century, since the introduction of Lean principles as a set of procedures and recommendations aimed at increasing industrial productivity by eliminating process inefficiencies. The principle of Lean philosophy relies on the Pull strategy, a production methodology that allows to respond to real market demand by assembling the required number of products according to limited buffers and constrained production timing. As a consequence, this method can increase workers' workload and reduce their control over tasks (Landsbergis et al., 1999), as well as raise safety risks compared to traditional Push systems, in which production is based on market demand forecasts and is characterised by larger production buffers and more flexible processes (Brown and O'rourke, 2007). Discussions about the implications of the Pull strategy and of Lean Manufacturing remain relevant in view of the Fourth Industrial Revolution, with the literature focused on optimising the integration of these approaches, neglecting their impact on workers (Frank et al., 2025).

Therefore, this thesis aimed to design and validate an experimental protocol to investigate occupational stress in Manufacturing, adopting a worker-centred approach. Moreover, through the implementation of this protocol, this thesis intended to investigate the main stress causes associated with the Pull and Push production approaches, considering the effect of sociodemographic and contextual variables.

The protocol was developed by Apraiz et al. (2023) within the NO-STRESS Manufacturing project and consists of three phases: before, during and after the task execution.

The first phase includes the consent form signature and the collection of sociodemographic information and baseline data, by providing experimental details to participants. Then, they perform the tasks while neurophysiological data are recorded and, after the tasks, the psychological perceptions of participants are recorded through questionnaires.

This protocol was validated in a preliminary experimental campaign conducted in a real industrial site with real workers as participants. The workers performed two traditional manufacturing tasks: assembly and quality monitoring. The findings demonstrated the efficacy of the protocol and the neurophysiological measurements incorporated in detecting even slight changes of stress indicators and in performing comparative analyses of stress levels between the activities within a task, between different tasks and between subjects with different sociodemographic characteristics. The final protocol incorporates a pre-experiment stage for participant recruitment and experiment design, and a post-experiment stage to guide researchers in effective data analysis.

This protocol was implemented in a definitive experimental campaign conducted in laboratory. It involved an international sample of participants who performed assembly tasks in two experimental conditions differing in the production approach simulated (push vs pull), the provided assembly instructions (free assembly procedure vs constrained) and the takt time (average vs short time).

Descriptive analyses of both psychological and neurophysiological data indicated that the Pull condition was the most stressful and time-demanding. The Push approach involved higher workload, mental and physical demands. Differences in stress and workload in the two conditions were not

statistically significant. Data analysis showed that both stress and workload indicators changed according to the gender, age and seniority of participants, to the time of the day in which the experiment was performed and the sequence in which the tasks were proposed.

Finally, these studies demonstrated the protocol flexibility in being adopted and adapted to investigate work-related stress in different experimental contexts and conditions. Future studies may deepen the effectiveness of the procedure in detecting the effect of environmental factors on stress, and include also ergonomic or biological techniques for measuring work-related stress.for measuring work-related stress.