Summary

This doctoral dissertation focuses on the analysis of the Human-Robot Collaboration (HRC) paradigm in manufacturing. HRC is one of the cornerstones of Industry 4.0 and the emerging Industry 5.0, and its purpose is to combine human and robot skills for the achievement of a task. The study and development of such a paradigm requires a multidisciplinary approach, requiring attention to both technical and human aspects. This dissertation highlights this characteristic by presenting a contribution to the holistic development of HRC in manufacturing. In details, the dissertation consists of four main chapters.

Chapter 2 provides an overview of HRC and a conceptual framework for its evaluation. In section 2.1, a literature review on HRC is proposed, also highlighting the differences from the concept of Human-Robot Interaction (HRI). In section 2.2, a holistic conceptual framework for evaluating HRC is proposed. In this section, the dimensions and sub-dimensions of the framework are explained in depth with several references to the literature. In addition, evaluation methods for each sub-dimension are provided. Section 2.3 illustrates two examples of application of the framework, one in manufacturing and one in healthcare, highlighting its generality.

Chapter 3 has a twofold purpose: to show the critical usage of the conceptual framework for evaluating HRC in a real manufacturing context and to propose a methodology for comparing and choosing between different collaborative configurations. Section 3.1 introduces a real-world case study of a collaborative task in the automotive domain. Section 3.2 shows the use of the framework to compare different configurations of a collaborative task.

Chapter 4 focuses on the need to equip collaborative robots with social intelligence in order to establish a more natural interaction with humans and provide more support during shared tasks. This goal can be achieved by implementing affective computing techniques. This chapter presents a state-of-art concerning the implementation of affective computing in HRI applications. Section 4.1 provides an overview on affective computing, which is a research area devoted to the development of systems capable of recognizing, interpreting and simulating the human affective state. Section 4.2 explains the data collection methodology and the analysis dimensions. Section 4.3 contains the state-the-art on the implementation of affective computing in HRI in three main contexts: healthcare, services, and manufacturing. The study shows that the implementation of affective computing in manufacturing is still in an embryonic state. Therefore, in Section 4.4 a number of research challenges are highlighted in order to promote a full deployment of affective computing in manufacturing.

Chapter 5 presents an experimental activity aimed at exploring the effect of different configurations of a collaborative robot on user experience during an industrial collaborative task. In particular, the effects on aspects related to the perceived quality of interaction, affective state, and stress are examined. One of the main novelties of this study concerns the analysis of stress through the physiological response of the user collected through a non-invasive biosensor. Section 5.1 details the methodology, experimental setup, and instruments used in the study. Section 5.2 shows the results of the study reporting both a descriptive and regression analysis. The descriptive analysis provides an overview of the data collected. The regression analysis contains a more in-depth exploration of the effects of the experimental factors on the different response variables through the use of regression models. Section 5.3 provides additional considerations and interpretations of the results obtained.

The concluding Chapter 6 summarizes the original contribution of the dissertation, focusing on the benefits, limitations and possible future developments.