INNOVATION AND THE WARLIKE PHENOMENON

Lucas Pereira Rezende[1], Rafael Ávila[2]

Introduction

War is a human activity responsible for social, political and economic changes. Also, much of our history is meddled with the history of war (Ávila and Rangel 2009). Although it is understood that war is not solely responsible for these changes, it is, nevertheless, one of the phenomena that most directly generate ruptures in these spheres. War is also responsible for several technical and technological changes, and it has generated some significant innovation processes with great impact on the way of life of societies throughout history.

This article aims to contribute to the inclusion of the specific discussion of technological breakthroughs in warfare in the field of innovation, contemporarily dominated by discussions of the management area. Taking World War I (WWI) as case study, we show the impact of innovation in warfare, and vice versa, pointing out how that war, more than others, brought innovations in the various fields of the war phenomenon.

To that end, this article is divided into three sections. In the first section, we discuss the definition of war, its main dimensions, nature and aspects. In the following section, we present a brief evolution of the history of warfare, highlighting some technical and technological changes and disruptions in some of the most important moments in human history. Later, we present

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[1] Associate Professor of the Department of Economics and International Relations of the Universidade Federal de Santa Catarina (UFSC). E-mail: lucasprezende@gmail.com.

[2] PhD candidate at the Information Science Doctoral Program of Universidade Federal de Minas Gerais (UFMG). E-mail: rafael.avila@animaeducacao.com.br.

some of the major innovations introduced by WWI. Finally, in the last section, we discuss the relation of the types of innovation and warfare, in light of the history of World War I.

In this article, the term innovation is generally understood as a complex process that usually starts with a new idea, goes through the solution of a problem and reaches the creation and use of a new good (product or service) of real economic or social value[3]. In this sense, invention differs from innovation. The former relates to creating something new, not necessarily considering the market, while the latter has to do with change, with doing something differently, or with changing the environment and/or the market where it is inserted, without necessarily having the concern with creating something technologically new.[4] Challoner (2009, 08) states that "invent is to create something new - something that was not there before. An invention may be an idea, a principle (such as democracy), a poem, a song or a dance." For us, technology "is the practical application of our understanding of the world to achieve what we need or want to do." (*idem*)

Another important aspect to be noted concerning innovation is the degree of novelty involved in it. The innovations can range from just an improvement in one component, for example, which Tidd, Bessant and Pavitt (2008) call incremental innovation, to a total remodeling, advance or improvement in a system or product that changes the way the thing is or is done, which is called a radical innovation. Radical innovations sometimes generate disruptions, discontinuous changes. There are also innovations in architecture, when the mental modes and sources of knowledge are basically remodeled (Tidd, Bessant and Pavitt 2008). In the last section, we revisit in detail the kinds of innovation that these authors indicate.

Many historians, as well as military historians, have devoted themselves to the study of the relation between human evolution and the

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[3] Tidd, Bessant and Pavitt (2008) separate innovation into four broad categories: 1) Product innovation - changes in the things (products/services) that a company offers; 2) process innovation - change in the way in which products/services are created and delivered; 3) position innovation - changes in the context in which products/services are introduced; 4) paradigm innovation - changes in the underlying mental models that frame what the organization does.

[4] Lecture note; "Network, Knowledge and Innovation" discipline; Information Science doctoral program, UFMG, 2011.

aspects concerning the war phenomenon, among them: McNeill (1982), Jones (1986), O'Connell (1989), Creveld (1991), Keeley (1996) and Grant (2005). Others have devoted themselves to showing some specific aspects of warfare, and how these issues have evolved in the course of conflicts. Creveld (1977), who focused on the discussion of the evolution of logistics throughout history, and Engels (1980), by discussing the logistics of the wars of Alexander of Macedon, are good examples. There are still good works devoted solely to the technical and technological developments in weaponry, equipment and processes in warfare; among them, those of McNaught (1984), Norris & Fowler (1997) and Dunnigan (2003) are worth underscoring. One author in particular deserves attention for having devoted his entire life to the discussion of technological innovations in a specific conflict (World War I): John Terraine. Terraine has a dozen books on one of the most important conflicts of modern history and, therefore, some of his discussions will serve as examples to the points made in this article. Headrick (2009) is also an author who brings in detail the evolution of technology throughout history, pointing out, like few others, its impact in the war phenomenon, too.

Warfare

Carl Von Clausewitz demonstrates in his work that warfare is an utterly political phenomenon. According to the author, "war is [...] an act of force to compel our enemy to do our will" (1993, 83). This means that war is the use of physical and moral force in order to oblige others to do what we want. The desire would be the goal we want to achieve, while the force would be the means to achieve it.

From this concept of war, it is possible to understand that it has ends (the will, the political objective that is sought) and means (use of force)[5]. However, war itself is a means used to achieve political ends[6]. These purposes,

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[5] "Force, according to the author, encompasses both the physical dimension (attributes) and the moral dimension (willingness to fight)." (Ávila and Rangel 2009, 59. Our translation.)

[6] It should be noted that there are other mechanisms to achieve what we want, being the war just one of them. Diplomacy has been identified as another mechanism, sometimes in total opposition to war as an instrument of policy. This misconception is demonstrated by Schelling (1967) in his book "Arms and

although varied, are always political in nature. "The use of force would be the *means* in warfare; to impose our will, its *object* (I:1:2:8)."

From this conceptual definition, Clausewitz may derive his theoretical conception of the elements that characterize warfare. One of the most important elements, however, is that of politics, the reason that leads to war. It is this element that determines how much force will be used in war.

> According to Clausewitz, the political object will determine the military objective to be achieved and how much effort it requires. As the author points out, the same political object can elicit different reactions from different people, or different reactions from the same people, but at different times (Ávila and Rangel 2009, 61. Our translation.)

Clausewitz also explains that all wars would have two main sides: attack and defense. In general, the side that decides to change the *status quo* is considered the attacker and hence is the side that needs the situation to be modified. In contrast, the side that wants to maintain the *status quo* is considered the defense. For the latter, it is enough for things to remain as they are[7].

The author also presents, along with the political, the other two dimensions in warfare: 1) tactics, which refers to the use of force in confrontation; and 2) strategy, which refers to the use of confrontations to achieve the purpose of the war. In this sense, when deciding on which weapons to use, number of combatants, and where to act, this is the tactical dimension. When one decides on the sequencing of combats, their order, pauses, advances and retreats, it roughly concerns the strategic dimension.

It is also worth noting that the discussion of Clausewitz leads to what he calls the paradoxical trinity (or strange trinity in the terms of Diniz 2002).

Influence", highlighting what he calls coercive diplomacy, something between soft diplomacy and war itself.

[7] Clausewitz will demonstrate that attack and defense are not antagonistic poles in a war in the sense that one is the complete opposite to the other. In fact, many times, they have completely opposite goals, but their peculiar characteristics prevent us from saying that one is merely the counterpart of the other. They would be, according to the author, two distinct forms of struggle, while the defense would be the strongest form. For this discussion, refer to the works of Diniz (2002), and Diniz and Proença Jr. (2006).

The trinity comprises three elements in warfare, which are implemented by three different actors and therefore define their roles in the conflict.

> According to Clausewitz (1993), war is a strange trinity, composed of primordial violence, hatred and enmity; influenced by the play of chance and probability; and rationally subordinated to politics. The primordial violence, hatred and enmity are linked fundamentally to the people; luck and chance, to the armed forces and their commander; and rationality to the government. These three social instances – the people, armed forces and government – would have the function to produce, i.e. keep the war effort, fight, or face the opponent and decide, respectively (I; 1; 28; 101). (Ávila and Rangel 2009, 61. Our translation.)

It is important to note that the theoretical discussion of Clausewitz is not concerned with the specific determinations about where to fight (land, sea or air), when to fight (past, present or future), and with which weapons to fight. This discussion, and that on where lies the impact of technical, procedural and technological innovations, do not annul and do not directly interfere with the aforementioned theoretical construct. Although they are important, and generate effects during a war or combats, their effects do not alter the nature of war.

> It is concluded that, for Clausewitz, war is an instrument of politics. It is politics that defines why we fight. It is politics that, in the exercise of reason, and in accordance with the available means of force, decides for the path of virtue. However, war will not be a nonstop action of violence. There will be breaks. Breaks arising from the asymmetry of force between defense and attack and that allow for the strategic dimension besides the political and tactical ones. In addition, war is an interaction of three social instances (government, people, and armed forces and their commander), each one being influenced more directly by some inherent war element (reason, passion and chance) and with a function in it (decide, produce, combat). (Ávila and Rangel 2009, 62. Our translation.)

In the following section, we will address more specific aspects on how people have fought and, therefore, on where the innovations and technological breakthroughs have greater effect.

Combats

War, as discussed in the previous section, is a clash of forces, each trying to impose itself on the other. Although all wars present the three dimensions proposed by Clausewitz - political, tactical and strategic - these differ from war to war, and even within the same war between the sides that are fighting - attack and defense. One can fight with the objective of conquering a parcel of a territory, the total subjugation of the opponent, or the control of a certain resource; one can fight using sticks, stones, supersonic jets, or submarines; one can fight in the ocean, in the desert, or on a mountain range. These changes obviously impact the three dimensions of war, but they do not withhold them from the analysis.

Innovations in the way of fighting (tactics and strategy) arising from changes in the processes, techniques, technologies and weapons do not change the nature of war, but they can interfere in the course of the conflict. However, and as shown by Diniz, Proença Jr. and Raza (1999, chap. 5), one must be careful when associating technical and technological changes with the victories and defeats in war[8]. The issue is not so simple. One must not be spoiled by a certain determinism generated by the "technological imperative", something that Dunnigan (2003) and the U.S. military doctrine have insisted on defending[9]. Most of the time, innovations in weaponry alone do not produce definitive results in wars, after all; moreover, as the history of war has demonstrated, most of the time, when one side introduces an innovation, either

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[8] The same is held for the impact that a sudden climate change has on war. The effects it produces are experienced in combats and war, but not to the extent of defining their results. A great example of this is the association of the defeat of Napoleon Bonaparte's campaign in Russia with the harsh Russian winter, something that Clausewitz himself proved to be a mistake in his "Campaign of 1812". Or even associating the defeat of the Nazis with the climatic conditions of Russia again, then in World War II. Although weather conditions have their effects, victories and defeats result from multiple variables, being climate, geography, armaments and innovations portions of this set.

[9] There are innovations that bring benefits to either side in war, but that does not mean that each and every innovation by itself produces such effects.

it is quickly absorbed by the counterpart or mechanisms to minimize the effect of this change in the combats and war are created. It is as if the disruption generated a momentary imbalance and that, in the course of the fight, this rebalancing was resumed. Therefore, victory and defeat in a combat and wars result from a complex combination of multiple variables; to reduce them to one or another aspect incurs a grotesque mistake. Later in the article, we will present some innovations that were significant to the domination of one people over another that, even so, did not represent the technological supremacy over other aspects of warfare (tactical, strategic and political).

Before returning to the debate on the impact of innovations, a brief discussion on how war has been fought is worthwhile.

Traditional forces in war were divided according to the way in which they fought. Either they fought by shock or they struggled through throwing weapons. In general, few innovations have been created since these combat units.

> There are four types of units of force in ancient and medieval warfare: 1) light infantry, mainly archers, javelin throwers, stones throwers (through sling), etc. They fought through combat of throwing or, for some, missile fighting. They did not use to wear body armor or protection; 2) heavy infantry, consisting of swordsmen and spearmen. They generally used swords, axes, maces, spears, clubs and shields. They used to wear body armor or protection, which turned them into a combat unit slower than light infantry. This is the case of Greek *hoplites* or Roman legionaries; 3) light cavalry. Knights used bows and arrows and/or darts, fighting through missile combat. They did not wear body protections; and 4) heavy cavalry. The fighters of this unit used swords, shields and spears. They used to wear body protection and some units, like the Iranian knights, put up armor even on their horses. (Ávila and Rangel 2009, 35. Our translation.)

These unit models existed from antiquity to the medieval period[10].

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[10] For an interesting discussion on these combat units, their characteristics, as well as which has tactical advantages over which, refer to Jones (1986).

In fact, the existence of cavalry was made possible by the process of domestication of horses, which dates back, according to Grant (2005), to 1700 BCE, the same period in which combat chariots were devised. Still on cavalry, its supremacy while fighting unit, and which would significantly characterize the Middle Ages, only happened in the eighth century CE, when the stirrup was created and alfalfa began to be grown on a large scale (Ávila and Rangel 2009). McNeill (1982) and Creveld (1991) consider the invention of the stirrup as something utterly important in medieval warfare because of the stability it gives the rider, an innovation that greatly changed the relationship between the cavalry, especially the heavy one, and other combat units.

Still on innovations that meant advantage over others, take, for instance, the change of casting technology and use of bronze (3500 BCE) for the casting technology and use of iron (1400 BCE). Both the agricultural tools and the arms themselves, with the introduction of iron, became more resistant, and not only did this impact the production of food but also the war itself. Iron-based weapons and body protection proved decisive in the struggle against people who used bronze-based weapons and protections. In fact, the domination of many Greek people by the Dorians may have been directly related to the mastering of iron by the latter (McNeill 1982).

Agriculture as well as the mechanisms of food-storage were crucial in this period. The dominant civilizations at the time were those whose agricultural capacity was superior to others'; after all, the size of the force depended directly on the productive capacity of the people.

> The wars of this period, and especially the duration of campaigns, were directly influenced by the ability that the rulers had to stock up food and fodder for their armies. In other words, the size of the force, as well as its ability to operate in time and space, depended fundamentally on the food resources available for itself (food) and for its animals (forage). As long as there were resources, there would be war. (Ávila and Rangel 2009, 37. Our translation.)

In this sense, as important as anything else, the innovations in agriculture (plow, animal traction, mills and silos) were equally or more important than the invention of an arm or any given war process. Nevertheless,

these innovations do not relate so directly to war. From the ancient period to the medieval age, there were few disruptive innovations that directly affected war. Some, however, stand out: the invention and use of war chariots and compound bow. Both were created around 1800 BCE and had a great impact in ancient warfare.

Another important set of innovations for this historical period were the siege weapons. The rise of cities and the constant harassment they suffered - especially by the nomadic tribes - meant that they needed a more complex system of protection. The solution found was immuring them. In doing so, cities would be less vulnerable to the attacks and could be protected by a smaller number of people. However, the enclosing of cities led to the invention of siege weapons[11]. As stated above, an innovation on one hand leads to the creation and invention of a counterpart; in the case of walls, the siege weapons.

From these innovations - chariots, compound bows, siege weapons, stirrup - war would remain unchanged for the following 2500 years. It is only at the end of the glorious Greek period, with Alexander the Great, that some innovations would emerge. According to Engels (1980), Alexander was responsible for developing a complex logistics system, something that was very useful and enabled the conquest of much of the known world at the time. In an earlier period, Philip of Macedon, father of Alexander, had already introduced some innovations in the Greek army. They were not disruptive innovations, as were the ones mentioned above, but rather incremental changes that produced devastating effects in the wars of Greeks with the rest of the barbarian world[12].

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[11] Among the most famous siege weapons are onagers, trebuchets, battering rams and catapults, besides the assault ladders and platforms. To learn about these arms, refer to Griess (1985), and Parker and Cowley (1996).

[12] Among the innovations in the Greek/Macedonian army that allowed Alexander to dominate almost all the known world, there were: the expansion of the Greek spear from 1.8m to 3m, which allowed the Macedonian forces to reach their adversaries before being reached; the introduction of the "sacred band", a heavy infantry unit, deeper than the traditional Greek phalanx, which was positioned in the forces' left and was responsible for breaking the opposing phalanx; the introduction of an intermediate unit between light and heavy infantry, the *peltasts*, which enabled the Macedonians to increase the spaces between their fighters, creating mobility and flexibility, and to break the unity of opposing forces.

After Alexander's death, world history focused on the rise of the Roman world. Rome had one of the largest and best-trained armies of all time, and it dominated the history of the West for nearly 700 years. However, the great Roman innovations did not occur on the battlefield. The Romans were skilled engineers and builders, making bridges, roads, fortifications and aqueducts. In war, Romans tried to enhance the known armaments, such as siege weapons, and improve the processes of casting metals.

From the fall of the Roman world through the end of the medieval era, only one innovation would bring profound, yet not immediate, changes in the way people fought: gunpowder. In the interim, however, the creation and introduction of the beast had a significant impact in war in this period.

The Medieval Era was characterized by the dominance of heavy cavalry. Knights established themselves as the supreme fighting unit, assisting the consolidation of certain fiefs and their overlords.

The invention of the crossbow was remarkably significant because it broke the military and political order of the time; after all, knights were the superior "caste" and, with the crossbow, they could be killed by any citizen, something inconceivable hitherto. "This weapon, by rendering vulnerable the condition of knights, who were mainly members of the nobility, could create conditions for a political and social upheaval from the plebs, so the church decided to ban its use against Christians (1139 CE)." (Ávila and Rangel 2009, 46)

The great innovation that changed the way of making war in the turn from the medieval period to the modern era was gunpowder. It must, however, be remembered that gunpowder was invented in the fourteenth century CE in China, but its employment in war, in total substitution to other weapons such as the crossbow, for example, would happen only centuries later. In fact, gunpowder took some time to become the crucial element in warfare.

Associated with the invention of gunpowder, some innovations are also noteworthy and gradually turned firearms into the most important on the battlefield: improvement in the metal casting processes (which enabled the forging of lighter cannons); creation of the recoil system (which allowed the gun to shoot and remain relatively steady for the second shot); development of different types of ammunition (with different functions and effects). "War, as designed in the fifteenth century, would last until the mid-nineteenth century."

(Ávila and Rangel 2009, 49). After cannons, European fortifications underwent significant modifications.[13] Heavy and very difficult to transport, cannons had rapid employment in naval forces, which would be decisive for the European conquest of new territories. Thus, upon the disruptive innovation that was gunpowder, several incremental innovations developed during these centuries, until the predominance of firearms on the battlefields in the mid-nineteenth century. It is worth noting that there were five centuries from the appearance of gunpowder on the battlefield until its supremacy in warfare.

Another important innovation, in terms of organization rather than product or process, was the establishment of professional military institutions.

> Between the seventeenth and eighteenth centuries, in general, there was the development of the commercial/military complex, as well as the bureaucratization of the military administration, organizing its forces in a modern way. The units began to professionalize decisively, creating an *esprit de corps* and an increasingly complex chain of command to respond to. (Ávila and Rangel 2009, 50. Our translation.)

The armed forces became of exclusive control of states, and soldiers became fully professional. Industrialization, a process that would significantly change all aspects of the relations of human communities, also changed the way of making war.

> The forces, which were composed more of warriors than soldiers for part of history, would then be composed of men understood as parts, replaceable as cogs in a machine. Men who could be quickly trained in the basic tasks of a force: dig for trenches; march and shoot. (Ávila and Rangel 2009, 50. Our translation.)

With the improvement of firearms, combat units changed. Only three arms remained: infantry, cavalry and artillery. As a tactical simplification took

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[13] See chapter 03 of Paret (2001) about Vauban, one of the greatest architects in the history of military fortifications. See also, about the history of the innovations of artillery and fortifications in Brazil, Mori (2003).

place, armies became increasingly numerous. "To cope with such huge forces, maps, telescopes and even the stopwatch were developed." (Ávila and Rangel 2009, 51). In addition, the logistics system was developed.

> Another "innovation" of the period was the full participation of the nation in the war effort. The people, who often stayed away from wars, became fully incorporated. War became total by then. Either the people took part as a fighting force, and, indeed, armies could reach the houses of hundreds of thousands, or the people (...) was a key element in the war effort through its productive capacity. (Ávila and Rangel 2009, 52. Our translation.)

In the mid-nineteenth century, some innovations would shape how the war would be fought in the following century. Although some of these innovations had nothing to do with war, they would bring direct impacts to it. The first change of the wars of the eighteenth to the nineteenth century, and which would have its peak in the twentieth century, was the inclusion of the whole nation in the war effort, which allowed building an army of masses, as previously exposed. The industrial logic created by England would soon be incorporated into the armed forces.

> The way the world economy was industrializing and mass-producing showed that war could follow the same principle. And so it did. The First World War is thought of as the culmination of the logic of mass production, for even soldiers were regarded as pieces. (Ávila and Rangel 2009, 52. Our translation.)

The invention and development of railroads, which could carry this mass of soldiers, besides being able to carry supplies of food and ammunition in distant theaters of operations, also significantly impacted warfare. Moreover, the emergence of machine guns and repeating rifles, as well as larger, lighter and more lethal cannons (which started to shoot indirectly and therefore needed mathematical and statistical calculations), quickly transformed the tactical aspects of war. Soldiers, to defend themselves, would need to entrench themselves. Upon that, new artillery ammunitions were either improved or created (the howitzer was created, projecting a more angled shot, unlike guns,

which projected straighter shots). In the nineteenth century, it was first seen the use of poison gas on the battlefield (See Norris and Fowler 1997).

At the turn of the twentieth century, new weapons would emerge, such as submarines, aircraft and tanks, something that we will see in detail in the following section. It is worth noting, however, that the wars throughout history either were responsible for creating or improving products (weapons), processes (manufacture of gunpowder) or organizations (military academies), for example, or incorporated the inventions of other spheres into its purpose (rail, ballistic engineering, etc.). In the next section, the emphasis will be on the war that witnessed the debut of the largest number of inventions and innovations in human history, World War I.

World War I (1914-1918)

The First World War was a conflict that brought together dozens of countries at various locations on Earth and that lasted four years, from 1914 to 1918. Its outbreak happened with the episode of the assassination of the heir to the Austro-Hungarian throne, Archduke Franz Ferdinand, as an excuse. However, the reasons that led to the confrontation between the major European powers at the time are many others. The most important aspect was undoubtedly the questioning of the *status quo* by Germany, which did not have the same powers and prerogatives that, for example, France and England did. Germany, the emerging power that was developing the most in Europe, began to fight politically for greater political and economic integration into the international arena, but its rivals systematically restrained it. A complex system of alliances was established so that the entry of a country in conflict would lead to the entry of all others. And this was exactly what happened[14].

> This alliance system, which had been forming since the late nineteenth century, had two major parties at the beginning of the war - the Triple Alliance, originally composed of Germany, Austria-Hungary and Italy,

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[14] As previously noted, John Terraine is a leading expert in World War I. Altogether, there are 11 books devoted to this conflict. Two of them will be addressed in this section: *White Heat: The New Warfare 1914-1918* and *The Smoke and the Fire: Myths & Anti-Myths of War 1861-1945*.

having the latter moved to the other side in 1915; and the second party being the Triple Entente composed of Britain, France and Russia. (Ávila 2005, 17. Our translation.)

According to Terraine (1982), the main feature of this war was its scale. At the very beginning of the conflict, six million combatants were already on the battlefield. This large-scale mobilization was associated with various technological developments outlined above and that had been taking place since the mid-nineteenth century (Terraine 1982, 21-43).

> The deployment and positioning of forces were facilitated by the large number of railroads. These railroads linked the producing centers to the battlefronts. They allowed, thus, rapid movement of forces throughout the theater of operations, in addition to their supplying. The wired telegraph, in turn, allowed communication between forces and, therefore, the relocation of the parts in the theater of operations. (Ávila 2005, 18-19. Our translation.)

The increased cargo capacity via maritime shipping was also key to the logistics of WWI. According to Headrick (2009), ships' cargo capacity has increased fourfold with the advent of steamships from the late nineteenth century through the early twentieth. According to the author, much of the growth was due to the increase in the size of ships: around the 1870s, a ship of two thousand tons was considered large. In 1912, the Titanic, the largest ship in the world until then, weighed forty-six thousand tons. Headrick (2009, 112) states that "what made the vast extension of railroads and shipping possible was steel", an innovation brought by the British in the late nineteenth century. The cheapening of steel made possible the construction of bridges, new types of weapons and even the storage of canned food.

It is also WWI that featured the full use of artillery, with dozens of different capsules and ammunition, in addition to the machine gun[15]. Moreover,

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[15] The machine guns will put an end to the traditional war cavalry, for a machine gun could decimate tens of knights mounting in charge attack. Horses would still be used in World War II (1939-45), but only to pull carts in the absence of trucks or for the displacement of small units.

this was the first war to witness the massive use of chemical weapons in an attempt to break the deadlock produced by the use of trenches (Ávila 2005). The leap made by chemical innovations after the war led to the development of products such as synthetic rubber, nylon, polyethylene, aspirin, vitamins and hormones (Headrick 2009). Other attempts to end the inertia generated by the trenches were bombing by airplanes (an instrument invented some years earlier and which initially had no military purpose yet was fully incorporated into the war); war tanks (introduced during the conflict, and which proved initially totally inadequate to break the lines of trenches[16]); the tactics of infiltrating trenches by soldiers with light equipment.

Besides these innovations, this war saw the large-scale introduction of land mines, something forbidden by the international Geneva conventions of the late nineteenth century, grenades, mortars, and even rockets. The fuel on which these war machines ran, due to the internal combustion engine, became petroleum-derived products, especially diesel and gasoline, over steam.

According to Terraine (1982), WWI was the war that observed the motorization. Cars, buses, motorcycles and trucks were employed, in addition to the train. In naval warfare, the innovations that served the purposes of this conflict were the wireless telegraph, water mines, torpedoes and torpedo boats, the submarine, and of course, the huge armored ships. None of this would have been possible without the advent of the combustion engine, about which Headrick (2009, 119) says, "no technology has had a greater impact on human life and the environment in the twentieth century than the internal combustion engine". Created by Italian-Irish Giacommo Marconi, wireless telegraph was made with the purpose of being sold to the Royal Navy and merchant ships. Developments upon this technology enabled, as far back as 1915, the landline telephone call between New York and San Francisco, and by radio telephone between New York and Paris (Headrick 2009).

Completing the scenario, with regard to aerial warfare, in addition to airplanes, balloons and dirigibles were employed on a larger scale. Prior to

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[16] The first tanks were extremely slow and noisy and, therefore, became easy targets for the enemy cannons. The tank would be an extremely important weapon in World War II, by associating speed, mobility and firepower.

WWI, the Zeppelins - inflated with hydrogen until then - already carried passengers in Germany, so, during the conflict, they were used for bombings in France and the United Kingdom (Headrick 2009). It was also during this period that the parachute was invented (Terraine 1982).

As previously mentioned, many of these innovations had already been seen in previous wars (1861-1865 American Civil War, 1898-1902 Boer War, 1905 Russo-Japanese War), but they were only employed at an industrial scale in the First World War. The American Civil War witnessed, albeit in a rudimentary form,

> repeating rifles, trenches and barbed wire, even machine guns; rifled cannons, mortars, explosive ammunition, flamethrowers, gas (...); balloons, armored trains, landmines, mines, signal lamps and flares, and the field telegraph; armored ships, rotating turrets, torpedoes, and even submarines (Terraine 1982, 11).

As mentioned before, even though some innovations had influenced war, they alone would not be responsible for the victory/defeat. O'Connell (1989) discusses that the emergence of an arm can generate two types of response patterns: a counter-response and a symmetrical response.

> The mechanisms which drive weapons proliferation, unlike most forms of natural reproduction, offer alternatives. Generally known as threat-response patterns, they can be reduced to two basic types. First, an adversary weapon can be met with a *counter-response*, an item of military hardware designed specifically to oppose the threat (...). On the other hand, there is the possibility of acquiring a weapon basically equivalent to the one held by the adversary. This can be termed a *symmetrical response*. (14. Emphasis in the original.)

There are two noteworthy examples of the use of a particular artifact and its countermeasures.

It is known that WWI witnessed the intensive use of poisonous gases, such as mustard and chlorine gases. Initially, the use of these weapons generated much turmoil in the trenches, facilitating the taking of some of them.

However, the initial physical and psychological impact of these weapons was supplanted by the adoption of some countermeasures, such as deepening the system of trenches, building shelters and bunkers, as well as by the introduction of gas masks and, subsequently, protective clothing and antidotes. Finally, as shown by Norris and Fowler (1997), despite its systematic use, the number of deaths by gas attacks during the four years of WWI did not exceed 91 thousand deaths (being 1.2 million the number of soldiers contaminated), something far inferior to the instant deaths caused by the atomic bomb attacks on Hiroshima and Nagasaki in 1945 (somewhere around 200 thousand deaths).

The other major innovation introduced in WWI and that, according to experts, would be largely responsible for the victory in the conflict was the tanks. As pointed out Terraine (1980), the expectation with the introduction of tanks, a kind of mobile and armored artillery, was that the system of trenches would quickly become obsolete. Tanks would terrify the soldiers, for their strength and firepower, and would be able to overcome the defense systems of the enemy. Their debut, at the Battle of Cambrai in 1916, had dubious results. Most tanks were destroyed by the end of the combat and the gains of land were insignificant. In 1917, according to Terraine (1980, 153-154), one hundred seventy-nine tanks were deployed, while 56% of them were quickly destroyed or immobilized.

The failure of this new weaponry was due to flaws of the equipment itself (armor, speed, damping system, immobility of the cannon), as well as the adoption of countermeasures and anti-tank weapons and techniques.

Terraine (1980, 173) summarizes the major social and technical changes of WWI, for being the first war: 1) of aviation; 2) with real submarine warfare; 3) of the internal combustion engines; 4) of mechanics; 5) of wireless telegraphy; 6) of artillery; 7) of effectively chemical warfare; 8) of mass production.

Consequently, during this period were developed metallurgy (especially steel), the chemical industry, electrical machinery, radio communications, turbines, the fuel industry, the optical science and hydraulic machines, for example (McNeill 1982, 292).

The other innovations presented throughout the text were enhanced in WWI or in its subsequent period and had significant use in the conflict that would follow, the Second World War (1939-1945).

Types of Innovations and World War I

Finally, it is worth advancing here the discussion on the innovations presented in the previous section in light of the types and categories of innovations outlined by Tidd, Bessant and Pavitt (2008)[17]. According to these authors, there are basically four major types of innovations, namely: 1) *incremental innovations*, which include improvements made on the design or quality of products; improvement in layout or processes; new logistic and organizational arrangements or new supply and sales practices [usually resulting from a process of internal learning]; 2) *radical innovations*, which break with what exists, inaugurating a new technological path; they are usually the result of R&D (Research and Development) and have discontinuous character in time and in different sectors of activity; 3) *innovations that generate changes in the technological system*, which occur when a sector or group of sectors is deeply transformed by the emergence of a new technological field. Such innovations are often accompanied by changes in the way of doing business, in the organizational structure of the companies, as well as in their relations with their markets; 4) *innovations that generate changes in the technical and economic paradigm*: they involve innovations not only in the technology used, but also in the social and economic fabric in which they are inserted. Obviously, some of the conceptual elements outlined above relate to administrative matters and the management area. However, we can make some inferences based on them for the case analysis.

Regarding the first, that is, *incremental innovations*, there were several examples in WWI such as cannons and howitzers, which had been improved since the fourteenth century; the tactics of trenches infiltration, which reorganized how to attack the fixed positions; the single-engined airplanes that evolved into twin-engined ones. Other examples are the development of land mines from the water mines and protective equipment against gas attacks.

The development of underwater communication technologies, which would evolve into the creation of the sonar and, later, the radar, were *radical*

17 Although the authors' discussion is mainly applied to innovation in business, it is believed that such a discussion can be transposed to the present debate.

innovations made possible by the First World War. Another example in the communications sector was the development of radio and field telephone, which would allow the evolution into the development of cellular devices.

With regard to *innovations that generate changes in the technological system*, the petrochemical industry and the chemical industry in general, which develop and improve respectively fuel and weapons of mass destruction may be included in this type of innovation.

Finally, and unfortunately, *innovations that generate changes in technical and economic paradigm* were not found in WWI. The creation of the General Staff and military structures, which changed how the armed forces are created, maintained, and used, and that even significantly shaped how the bureaucratic structures of states are established, could represent an innovation in this category, but they are nineteenth-century constructs. The development of the computer, which also falls in this category, is an invention linked with World War II.

Final Considerations

War generates changes in social, political and economic order, as well as in technical and technological dimensions. It is part of human history and, on several occasions, has shaped its course. War is also a political phenomenon and most of the paths it takes are due to the choices of decision makers in this sphere.

This article explained what war is in light of the theoretical conception of Clausewitz. It showed its fundamental characteristics - the political, strategic and tactical dimensions, attack and defense, as well as the strange trinity. It further argued that, although technical and technological changes happen in society, and which are later incorporated into the war dimension, or innovations in warfare that later come to be used socially, there is no change in the nature of the phenomenon. Innovations and technical changes can affect tactical and strategic dimensions, but they do not exclude them from the analysis of the war phenomenon. It is understood that it is dangerous to infer that technological changes alone can have direct relations with the victory and/or defeat in war. This approach, understood here as "technological imperative", has attracted

some great scholars. The phenomenon is much more complex and should be treated as such.

We also presented some innovations that have occurred throughout the history of war, many of which taking years to be fully incorporated from its invention, its improvement and into its military use. Among them, some were radical, other incremental; some referred to products, to processes and others to organizations that relate to the war phenomenon.

Even if we have treated the evolution of the "art of war" from antiquity through the twentieth century, we gave some prominence to the period from the mid-nineteenth century through the early twentieth century, a time when war changed significantly in technical and technological terms and when significant changes happened. It is likely that the way we still fight today has its main characteristics established in this period and, therefore, we made such analytical delimitation. It is noticeable, perhaps more in WWI than in other conflicts, the connection between the war phenomenon and investment in technology. Although such products, says Headrick (2009), bring great comfort for humanity in times of peace, their use in wartime brings frighteningly harrowing results.

> Nothing illustrates better the idea that power over nature gives some people power over others than the military consequences of the new technologies of the late nineteenth and early twentieth centuries. [...] From 1914 to 1918, the industrial nations turned their weapons on one another. To kill each other's citizens more efficiently, they devoted resources to new scientific research, accelerating the process of innovation. [...] Despite the heavy industry that stood behind them, soldiers on the front still had to walk across coils of barbed wire into a hail of bullets and clouds of poison, and they died by the millions. (Headrick 2009, 123-124)

We hope that this article has helped to demonstrate the relationship between the area of innovation and those of war, administration (management) and history of international relations. The connection between innovation and the war phenomenon has existed since the dawn of humanity - which is not necessarily a reason of which to be proud.

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Lucas Pereira Rezende, Rafael Ávila

ABSTRACT

This article seeks to demonstrate the connections between the history of the war phenomenon, or simply war history, with the debate on innovation. In this sense, this article presents some technical and technological developments and which were their impacts in wars and human history itself. The discussion was divided into three moments. First, the most relevant theoretical elements of warfare in the light of the work of Clausewitz were presented. Second, we briefly addressed the evolution of the war phenomenon throughout human history, focusing on some technical and technological changes of the late nineteenth and early twentieth centuries. World War I was the object of analysis in a greater depth. Third, it was discussed how the analyzed innovations relate to the categories proposed by Tidd, Bessant and Pavitt.

KEYWORDS

Warfare; Technology; Innovation; Strategic Studies.

Translated by Airton Gregório Martins