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THE EFFECT OF TRAINING AND TECHNOLOGY ON FRICTION IN ARMOURED COMBAT – CASE STUDY OF BATTLE OF 73 EASTING

O EFEITO DO TREINO E DA TECNOLOGIA NA FRICÇÃO NO COMBATE BLINDADO – ESTUDO DE CASO DA BATALHA DE 73 EASTING

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Abstract

The aim of this article is to determine if training and technology are directly or inversely correlated with friction during armoured combat, using the Battle of 73 Easting, which took place during the Gulf War (1991), as a case study. A historical review was carried out to describe the battle and the categorization proposed by Ferreira, Ramos and Franchi (2018) regarding the different types of friction was used throughout the study. The study methodology was an analytical single case study which included a qualitative and quantitative analysis. The findings revealed that training and technology directly affected attrition, giving the US forces the advantage in the confrontation, and that technology correlated especially to the "information" category of friction, while training had more consequences for the "individual" category.

Keywords: Armoured troops; Friction; Clausewitz.

Resumo

O presente artigo tem como objetivo determinar se o treino e a tecnologia se relacionam, de forma direta ou inversa, com a fricção observada durante o combate blindado, utilizando a Batalha de 73 Easting, ocorrida no transcurso da Guerra do Golfo (1991), como caso de estudo. Para tal, foi realizada pesquisa histórica para descrever a batalha e utilizada a proposta de categorização da fricção proposta por Ferreira, Ramos e Franchi (2018).

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A metodologia empregue foi o estudo de caso único analítico, com análise qualitativa e quantitativa. Foi possível concluir que o treino e a tecnologia influenciaram diretamente na fricção, desequilibrando o combate a favor dos norte-americanos, e que a tecnologia se revelou mais ligada à categoria "informações" da fricção, enquanto o treino teve mais consequências sobre a categoria "indivíduo".

***Palavras-chave*:** *Blindados; Fricção; Clausewitz.*

1. Introduction

Armoured vehicles are one of the most sophisticated pieces of war equipment and one of the most decisive weapons used in land warfare. It is used to exploit its main advantage, shock action, to gain an advantage over the adversary. Combining mobility with firepower, they are most useful when executing rapid and decisive manoeuvres, usually to close in on the enemy forces with the aim of destroying, neutralising or disorganising them (Brazil, 2019).

Therefore, to obtain the best possible performance, the soldiers who operate them must have a specific set of skills, such as quick decision-making and the ability to use efficiently the electronic and mechanical systems on board. In addition, several factors influence the evolution of armoured combat, such as weather and terrain conditions, the technical characteristics of the vehicles and the possibility of equipment breakdowns (Brazil, 2018).

This evokes the concept of friction theorised by Carl von Clausewitz in the 19th century. Even though his thinking was shaped by the Napoleonic wars (Strachan, 2007), his principles can still be recognised in modern combat, and his major work *On War* is considered one of the most influential books for contemporary Western military thought (Elward, 2010).

For Clausewitz, friction consists of all the factors that make what is apparently easy during planning difficult to execute (Clausewitz, 2010). He used the term in analogy to the friction between the parts of a machine, which cause it to gradually become less efficient, until the moment when it eventually stops fulfilling its intended purpose. Therefore, knowing the points of resistance would be the first step to improve the ability to achieve the intended goals, both in the case of a mechanical component or of forces engaging in war.

The equipment used in combat has grown in complexity since the Industrial Revolution. In fact, tanks were used on the battlefield for the first time during the First World War (the first of which was the British Mark I) (Brazil, 2021). Initially conceived to support infantry while crossing unprotected fields covered by machine gun fire, such as the terrain between trenches during the static phase of the western front, there were significant technical and doctrinal evolutions in tank warfare in the first half of the 20th century. During the Second World War, they became one of the crucial elements of the German Blitzkrieg doctrine (Do Nascimento & Dalla Costa, 2017). Later, as a result of the arms race that took place during the Cold War, the US and the Soviet Union invested heavily in developing their arsenals, both in terms of quantity and (especially) quality (Pecequilo & Marzinotto Jr, 2022). This led to a significant increase in the technology and combat capacity of armoured vehicles, while at the

same time making them increasingly complex. Therefore, crews require constant training to operate these vehicles correctly.

2. Theoretical and conceptual framework: Clausewitz's concept of friction

Carl von Clausewitz is widely regarded as the most famous Western military thinker, and his major work, Vom Kriege [On War] is considered the seminal book on Western military science. Since it was first published in 1832, it has been translated into several languages and studied everywhere in the world (Tiejun, 2011). Interestingly, this did not happen immediately: the first translation was published in 1846 in Holland, followed by the French version in 1849. Outside Germany, it was only after 1870 that his work began to garner interest, following the German victories in the wars of unification, which inspired the publication of the first English version in 1873. The book was only published in Japanese and Chinese on the eve of the First World War; in Spanish and Italian during the Second World War; in Norwegian, in 1973; and in Swedish, in 1991 (Pommerin, 2011). Today, his work is studied by military personnel all over the world: in 2011, authors from 18 countries wrote about the theorist's influence on their respective nations for *Clausewitz Goes Global*, a publication celebrating the 50th anniversary of the *Clausewitz Society*.

One of the concepts Clausewitz addresses in *On War* is that of friction. He asserts that "Friction is the only concept that more or less corresponds to the factors that distinguish real war from war on paper" (Clausewitz, 2010, p. 84). When one reads the book, it becomes clear that friction is, essentially, the difficulties that arise when executing all actions in a plan, to the point that, even though everything is rather simple in war, friction makes even the simplest of things becomes complex. Clausewitz (2010) introduces the concept in Book One (of a total of eight), and returns to it throughout the text, providing examples. He describes how friction disrupts the execution of combat actions due to fear, adverse weather conditions, obstacles, etc. Most importantly, he explains that the most relevant source of friction is the fact that military forces are composed of several parts – individuals, and that each of those parts can make it more difficult to execute the actions that constitute a plan, either by chance or by doing things incorrectly.

Given that *On War* is one of the works that most influenced US military theory and doctrine (Elward, 2010), and as Clausewitz argues that overcoming friction is vital to improve efficiency in war, this concept has been widely studied. Several authors, including Kellet, Keegan, Watts, Elward, Malkki and Gray (Ferreira, Ramos & Franchi, 2018), have proposed their own theories on what constitutes friction and their own characterisations of the phenomenon, updating its definition and elements to accompany the latest developments in the art of war. However, not all authors accept these interpretations as accurately representing Clausewitz's thinking. Pommerin (2011) comments that he is often misinterpreted due to being quoted out of context. Bassford (1994) is less forgiving, asserting that some authors are incapable of understanding Clausewitz's arguments.

When analysing current conflicts in the light of Clausewitz's concepts, two important difficulties emerge. The first is the historical context. As the epilogue to the 1933 German

edition of *On War* explains, Clausewitz was a Prussian officer who lived through the Napoleonic wars and participated in the fighting at Waterloo, or Belle Alliance, as a staff officer in the 3rd Army Corps under the command of General Thielmann, which formed the left wing of Blücher's troops, who participated in the final defeat of the French emperor (Clausewitz, 1933). The reality he experienced, which influenced his world view and philosophy of war was, naturally, very different from today's.

The second is the author's refusal to set definitive rules for war, because, in his view, each conflict has its own characteristics, which make it more elusive than a chameleon (Clausewitz, 2010). For this reason, while the concept of friction is fundamental to his military thinking, the specific chapter that deals with the subject – Chapter VII of Book 1 – only occupies 3 pages out of 618 in the German version (Clausewitz, 1933). Instead of a comprehensive analysis of the topic, in this section of the work Clausewitz provides a few examples to explain what friction is, but makes it clear that it would take several books to address all the possibilities of friction in combat, and that they would likely become outdated as time goes by.

The need to carry out systematic studies on the topic and conduct targeted and methodologically sustainable analyses have led several authors to attempt to categorise friction. One of the studies that did this in a methodical way, without making interpretations, was by Ferreira, Ramos and Franchi (2018). The work uses excerpts and examples taken from *On War* to explain the different types of friction described by Clausewitz. They proposed the categorisation illustrated in Table 1.

Table 1 – Friction according to Clausewitz.

Type of friction	Elements	Consequences
Individual	Danger	Fear, hesitation
	Physical exertion	Fatigue, exhaustion
	Stress	Distorted view of the facts
Environment	Terrain	Poor accessibility
	Climate / Weather	Uncertainties, delays
Information	False	Poor planning
	Inaccuracy	Poor planning, estimating what is known, deducing the unknown
Marches	Possibility of engaging the enemy	Planning how the reserves and fire support will be used
	Bad roads	Delays
	Mountainous terrain	Fatigue, exhaustion, longer marches, delays
	Physical exertion	Fatigue, exhaustion
	Lack of supplies and shelter	Disproportionate effort, fatigue, exhaustion, hunger, thirst, low morale
	Disease	Poor health, influence on combat power

Source: Adapted from Clausewitz (2010) and Ferreira, Ramos and Franchi (2018).

Many authors refer to the concept of fog of war as if it had first appeared in On War. The term refers to the combination of certain characteristics of warfare, such as uncertainty, chaos and complexity. But as a concept, it is difficult to differentiate from friction itself, to the point that in the US military, it is often referred to it as the "fog and friction of war" (Elward, 2010). However, if one analyses the book, it becomes clear that the term was not coined by Clausewitz. There is, indeed, a chapter on friction, and the concept is revisited throughout the book, the term "fog of war" is never mentioned, only the uncertainty of combat. According to Watts (1995), it is part of what Clausewitz originally called *Gesamtbegriff einerallgemeinen Friktion*, a unified concept of general friction which includes the problems encountered when attempting to execute precise actions in the face of the threat of death, the extraordinary physical demands of combat, the uncertainty about the information on which to base decision-making, and all types of unpredictable problems that make the easy so difficult in the conduct of war. Uncertainty appears under the "Information" type of friction, as Table 1 shows; therefore, in this article, the concept of fog of war will not be treated separately from that friction, and only the latter term will be used.

3. Methodological procedures

The main goal of this work is to determine if training and / or technology correlate with friction during armoured combat, either directly or inversely. The question that the study will attempt to answer is: to what degree can do technology and training correlate with friction in armoured combat? The answer was obtained by analysing a case study, the Battle of 73 Easting, which took place during the 1991 Gulf War, and is considered the last large-scale tank battle. During the confrontation, the US Army's 2nd Armoured Cavalry Regiment destroyed the main Iraqi defence, which consisted of personnel from the Tawakalna Division of the Republican Guard (Diaz et al, 2020).

Two specific objectives defined for the study: to categorise friction and describe the events of the Battle of 73 Easting. To understand the events of that battle, a historical review was carried out using official US Army documents, interviews given by the officer who led the US forces, among other works. To define the types of friction that Clausewitz theorised and identify their respective elements and consequences, a literature review was carried out using primary and secondary sources. The categorisation proposed by Ferreira, Ramos and Franchi (2018) was selected to be used in the study. Finally, an analytical single-case study was performed, using both qualitative and quantitative analysis, to determine if technology and / or training influenced the outcome of the battle.

This work is relevant because armoured forces are used as a means of decision in land warfare (Brazil, 2019), and are vital to achieving the desired end state in the Theatre of Operations. One way of achieving tactical success is to reduce friction. Therefore, it is important to identify the sources of friction in armoured combat, in order to eliminate it and ensure that the objectives of the war are achieved.

4. Presentation of data and analysis of findings

4.1. Case study: the armoured battle of 73 Easting

4.1.1. Overview

The Battle of 73 Easting is considered one of the most important battles of the Gulf War. It was fought between armoured forces of the coalition led by the United States of America (US) and those of the Iraqi Republican Guard. According to Howlett (2015), it was the largest tank battle since the Battle of Kursk in July 1943.

The battle took place in the hostile environment of the Iraqi desert, in a region with few reference points, which made navigation difficult. To solve the problem, the US forces identified each section of the terrain by the corresponding phase line in the military charts, which used the UTM system. In English, these lines are called northing when they run west-east, and easting when they run north-south. The battle was named 73 Easting because it took place along the north-south grid line 73 on the charts supplied to the US troops (Christenson & Zirkle, 1992). In practice, it took place west of Wadi al-Batin (Watts, 1995).

In the envelopment manoeuvre used during Operation Desert Storm in early 1991, the US VII Army Corps, commanded by General Frederick Franks, was positioned on the left flank. Its mission was to envelop the enemy and defeat the Republican Guard forces – which had been designated as the Iraqi centre of gravity (Lute, 1992) – from the west (McMaster, 2016). Three Iraqi Republican Guard divisions and three heavy divisions of the regular army were stationed in the region to secure their withdrawal via Basra. They were in prepared defensive positions and were familiar with the terrain (Biddle, 1996). Keeping this retreat route open was crucial for Iraqi manoeuvres because closing it meant losing the possibility of withdrawal (Howlett, 2015).

On 23 February, the VII Corps began its advance (Malouf, 2020). Its first vanguard was the 2nd Armored Cavalry Regiment (2ACR) (McMaster, 2016), which had been given the following mission:

> On order, 2ACR covers the western flank of VII corps as it occupies FAA UTAH. On G+1 [one day after the ground hostilities started], 2ACR attacks through the western flank of enemy defenses and conducts offensive cover operations in order to develop the situation for VII CORPS. Lute (1992, p. I-104).

According to Lute (1992), the goal was to gather information about the terrain and the enemy, defeat the initial Iraqi security forces, pin the bulk of the enemy forces in defensive positions to allow the US armoured divisions to advance and engage in combat, and exploit any opportunities that might present themselves. The limit of advance was set at the 70 Easting line (Malouf, 2020).

The 2ACR consisted of five subunits (Christenson & Zirkle, 1992): three armoured cavalry troops, with a total of 28 M1A1 Abrams tanks, 37 Bradley armoured infantry combat vehicles and six mortars; an air cavalry squadron (Sqd), referred to in the 2ACR as the "Dragoon Air Force", which included Apache attack and escort helicopters; and a support squadron responsible for administration and logistics. The radio call signs of the armoured cavalry

troops were "Ghost", "Eagle" and "Iron". The main difference between them at the time of the battle was that Eagle Troop had one more Abrams tank (it had ten, while the others had nine), and Iron Troop had one more Bradley vehicle (it had thirteen, while the others had twelve). Each troop also had one FIST-V fire support vehicle (basically, an M113 armoured personnel carrier adapted with a TOW missile launcher). In addition, each troop received a self-propelled howitzer (Bourque, 1997).

The Iraqi force was the 18th Brigade of the Tawakalna Division, which had modern export version T-72 tanks. These were the elite troops of the Iraqi army, and as such were the best supplied and the best equipped (Lute, 1992). It had 55 T-72 tanks, 3 T-55 tanks, 33 BMP-1 APC armoured infantry combat vehicles, 1 BTR-70 APC wheeled armoured vehicle, 1 M-113 APC armoured personnel carrier, 9 MTLB command vehicles, 2 SA-13 air defence missiles and 7 ZSU-23-4 air defence machine guns, 12 152mm towed artillery, 7 81mm mortars, 1 ACRV command vehicle, 1 ambulance, 1 BAT-M earth mover, 2 POL trucks, 4 utility trucks and 4 cargo trucks (Christenson & Zirkle, 1992). As a result, the Iraqi brigade had almost 50% more armoured vehicles than the US troops that they would face.

As stated above, their mission was to secure a retreat route via Basra. To that end, the force commander (Com), Major General Salah Aboud Mahmoud, who had graduated from the Infantry Officer Advanced Course at Fort Benning, US (McMaster, 2016), set up his defenses near a small village, which he fortified with anti-aircraft machine guns in ground mode and infantry. Given the lack of landmarks in the desert, the commander believed that the Americans would probably travel along the IPSA Pipeline road, which crossed the region and ran through the village. Therefore, he fortified it to force the US forces to bypass it from either south or north. When they did, they would be entering two kill zones where minefields had been laid. He dug in tanks about a thousand metres from that position, while infantry were protected by concrete bunkers and trenches dug between the armoured vehicles. He also reserved eighteen of his best T-72 armoured vehicles, positioned approximately 3 kilometres away. His plan was to drive the attacking forces into the engagement areas and destroy them. In addition, the Iraqis had the advantage of being very familiar with the terrain, having previously used it as a training ground (McMaster, 2016).

On 26 February, three days after the start of the advance from Saudi Arabia, the members of the 2ACR were tired, having slept for only a few hours – in CBRN defence suits – and faced adverse weather conditions (Howlett, 2015). The night before, the unit had managed to destroy about a dozen Iraqi armoured personnel carriers that belonged to the Republican Guard. Some of the vehicles contained military maps and barely used weapons, which suggested that contact could be imminent (McMaster, 2016).

The 2ACR vehicles were equipped with GPS, which would be used in combat for the first time. The troops only had to enter the destination data and the navigation was displayed automatically (Lute, 1992), which made it easier to execute the manoeuvre (shown in the diagram in Figure 1).

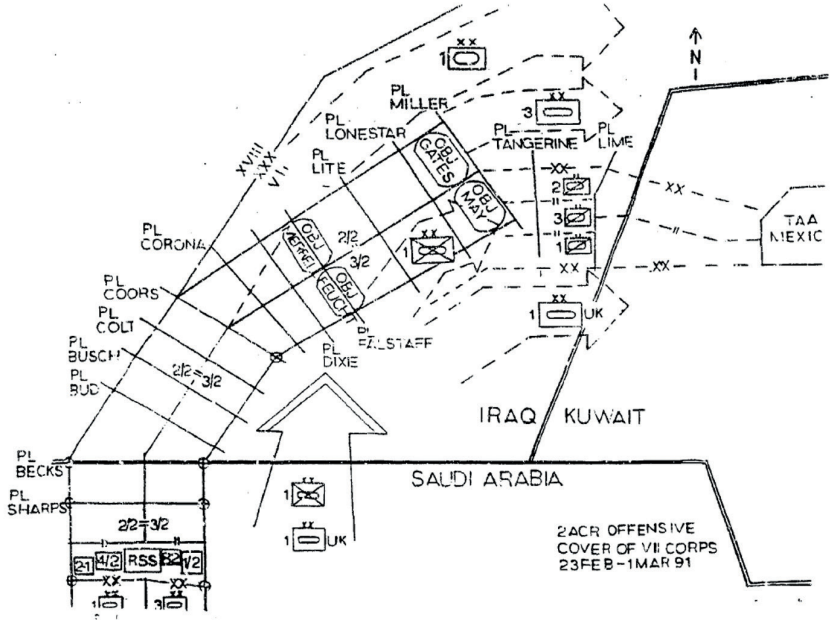


Figure 1 – General manoeuvre diagram, 2 ACR.
Source: Lute (1992, p. I-100).

4.1.2. The course of the battle

The initial contact in the Battle of 73 Easting was at 0830 hours on 26 February, when advanced reconnaissance of Ghost Troop engaged and destroyed an Iraqi personnel transport vehicle belonging to the Tawakalna Division – although the US forces did not know this for certain at the time. At 1000, Bradleys from the Ghost Troop destroyed another two armoured transport vehicles. Next, the Abrams garrison of the Eagle Troop commander, Capt. McMaster, engaged and destroyed a third Iraqi armoured vehicle before it could escape, from a distance of more than 2 km (Howlett, 2015).

There was heavy fog in the morning, after heavy rainfall during the night, and visibility was limited to about 200 metres. The fog cleared by the end of the morning, only to be replaced by a sandstorm. As a result, the air squadron was unable to provide support until halfway through the journey (McMaster, 2016). The forces on the ground were ordered to advance through the sandstorm to find the enemy and fix them in their defensive positions (Biddle, 1996). Gen Franks' initial plan was to have the 2ACR stop at Easting 60 and wait to be overtaken by the 1st Armoured Division at around 1800. However, due to adverse weather conditions which delayed the movement of that Grand Command, the order was changed to advance to 70 Easting, and the overtaking was to occur at 0200 D+1 (McMaster, 2016).

Around noon, near 60 Easting, a helicopter from the air squadron which had finally managed to take off spotted a dug-in T-72 tank which was quickly destroyed by the Ghost

Troop (Christenson & Zirkle, 1992). At 1300, the US forces stopped their advance, took defensive positions, reorganised and refuelled their vehicles (Howlett, 2015).

At 1500, they resumed their advance. The 2ACR's commander, Col Don Holder, used the following formation to engage the enemy: he deployed two squadrons forward, with the 2nd Sqd (Eagle) on the left and the 3rd (Ghost) on the right, and a squadron (Iron) following in reserve (Christenson & Zirkle, 1992). The Eagle Troop commander, Capt. McMaster, assessing that contact was imminent, reorganised his formation: the tank platoons would lead the advance to provide more firepower and armoured protection at the front and the Bradleys would follow close behind to protect the Abrams (Malouf, 2020), as illustrated in Figure 2.

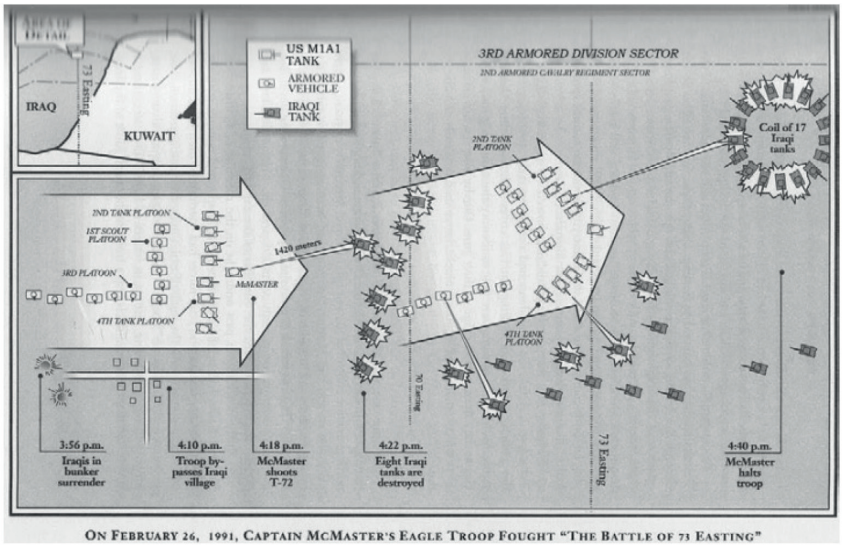


Figure 2 – Disposition of the 2nd Sqd of the 2ACR during the Battle of 73 Easting.
Source: Malouf (2020, p. 36).

The Eagle Troop was ordered to advance through another sandstorm to the 70 Easting line and fix the enemy there. At 1530, after destroying another three T-72s (Bourque, 1997), they reached the previous limit of the enemy's Forward Defence Area, where it came under fire from artillery and portable infantry weapons belonging to the Iraqi 18th Brigade. This forced them to close their hatches but did not stop their advance (Howlett, 2015). Unlike the Iraqi troops that the 2ACR had encountered until then, the Tawakalna Division put up a good fight (Biddle, 1996).

At 1618, they crossed the minefields (Howlett, 2015) and crested a ridge in the terrain, encountering eight T-72s in dug-in defensive positions at 70 Easting. They engaged with 120 mm calibre SABOT and HEAT ammunition from the M1A1 Abrams and destroyed them in four minutes (Malouf, 2020). They had arrived at the Iraqi strong points (Bourque, 1997).

Next, the 2ACR and the US Division artillery fire support attacked the second line of Iraqi defenses, destroyed troops and supply installations and disrupted the Tawakalna Division's

command and control. At the same time, an attack helicopter squadron supporting the 2ACR hit artillery and support positions in the rear, destroying at least two artillery batteries and dozens of support vehicles along the IPSA *Pipeline* road (Bourque, 1997) up to 12 kilometres from the line of contact (Howlett, 2015).

New targets were identified in depth. McMaster assessed that his troop was already engaged and decided to exploit this success. He ordered his platoons to cross 70 Easting and continue their advance. When the Regiment's operations officer asked him about this decision, he told his superiors: "Tell them we can't stop. Tell them we're in contact and that we have to continue this attack. Tell them I'm sorry" (McMaster, 2016, p. 4). Near 73 Easting, they engaged another eighteen T-72s and their mechanised infantry support (Malouf, 2020). After about 23 minutes of fighting, when they regrouped in defensive position at 74 Easting, the Eagle Troop had single-handedly hit 37 T-72s and 32 Iraqi armoured vehicles (Biddle, 1996), the equivalent of more than a half of an Iraqi heavy battalion (Bourque, 1997), without taking any casualties (Malouf, 2020).

At that moment, the other armoured cavalry troops of the 2ACR entered the battle. The Ghost Troop was engaged in an armoured counter-attack as a Subunit (SU). About 2500 metres from there, the T-72s were firing at the American Bradleys, but were too distant to be effective. The Abrams pressed forward and, at about 2000 metres, using their superior range, were able to destroy most of the Iraqi tanks (Bourque, 1997). At around 1700 hours, the Ghost Troop had also neutralised nine armoured transport vehicles when T-72 fire destroyed a Bradley, killing the gunner. After this, the troop commander believed that the main gun of his M1A1 had destroyed the responsible enemy (Howlett, 2015).

Meanwhile, the Iron Troop, which followed behind, attacked the Iraqi positions bypassed by the advanced troops, mainly inside the village, also destroying T-72 tanks and infantry vehicles (ibid.).

The sandstorm reappeared, lowering visibility to around 50 metres at 1800 hours, leaving the squadrons without air support again (Howlett, 2015). The Republican Guard continued to counter-attack in waves, suffering heavy losses, and 113 Iraqi armoured vehicles were destroyed (practically an entire brigade) (Biddle, 1996).

The squadrons then regrouped and reorganised because the battle was not over yet. But after 1800 its character had changed: the Iraqi infantry, believing that they would be protected by low visibility and darkness as the night was falling, tried to attack the Eagle Troop sector with portable weapons and anti-tank rockets. This SU managed to repel them using its superior firepower: it destroyed several troop transport trucks with TOW missiles, hit the T-72s and T-55s before they were within their weapons' firing range and scattered the infantry with mortar fire. In the following hours, at least two Iraqi tank companies, as well as hundreds of soldiers and their transport vehicles were neutralised (Bourque, 1997).

After that, there was only occasional machine-gun fire. Medics began treating and evacuating the wounded, the crews redistributed their ammunition, the bunkers were cleared with hand grenades and a resupply convoy was led through the minefield. A psychological operations team began broadcasting appeals encouraging the remaining enemies to

surrender, which led to the capture of the first hundreds of prisoners, including a brigade commander (McMaster, 2016).

The battle ended shortly after 2200: the 1st Infantry Division conducted a forward passage of lines in the Ghost Troop sector (McMaster, 2016) and the 2ACR moved into reserve for subsequent operations (Malouf, 2020). By the dawn of 27 February, the Tawakalna Division no longer existed (Bourque, 1997). In addition to material and human losses, the greatest loss for Iraq was morale. The Republican Guard, its elite force, was completely defeated at the start of the ground campaign, which led to feelings of inferiority and insecurity, undermining the confidence of the other troops (Diaz et al, 2021).

4.2. Findings

Having analysed the battle, there were several occasions that showed how friction can disrupt the practical execution of a plan, both for the US and Iraqi troops.

The first of these factors was obvious from the planning stage and was rather prosaic: the lack of landmarks on the terrain that could be used to aid navigation. This made it more difficult for the leaders of the various troops to execute their manoeuvres. The US forces were able to reduce the effects of this factor using GPS technology, which provided accurate coordinates instantaneously, eliminating the need to cross-reference data with topographical maps that showed the features of a terrain that largely featureless (Christenson & Zirkle, 1992). Nevertheless, the use of GPS did not completely remove friction from navigation. The 2ACR troops also used topographical maps. However, these maps were outdated: the IPSA Pipeline road, which ran alongside the Regiment's advance, could have been used to help navigation, but it only appeared on the maps prepared by the US Cartographic Engineering Laboratory, which were not distributed to the advance troops (Krause, 1992). Ironically, this turned out to be an advantage for the US troops: not knowing that the 2ACR troops were using GPS, the Iraqis made the road the centre of their defences, believing that the bulk of the armoured vehicles would move along that axis, and were taken by surprise when the attack came from their flank, through a desert with no reference points (Diaz et al, 2021). The scale used on the maps was 1:100,000, which did not provide much detail or show that the 2ACR was entering an old Iraqi army training ground (McMaster, 2016). The GPS system also had shortcomings: it was sometimes affected by the weather conditions, and, as the US troops relied on it to navigate, they had not taken enough compasses with them (Howlett, 2015), which in some occasions hindered their advance.

Ammunition was another technique used by the 2ACR to aid navigation. When they encountered the village, which had been fortified by the Tawakalna Division, the commander of the vanguard platoon ordered a TOW missile to be fired at the centre, to outline a zone of action and make it easier to assign each tank's firing sectors. This way, the Eagle Troop Abrams were able to fire nine cannon shots almost simultaneously, each hitting different sectors of the town, suppressing enemy machine-gun positions before they could begin hostilities. The 1st platoon, whose zone of action was to the east, continued to cover that sector, providing protection during the operation (McMaster, 2016).

Lack of reliable information about the enemy made it difficult for the Iraqi forces to decide on the best formation. According to the initial intelligence reports, they believed they would face a smaller force, not the main US armoured force (Bourque, 1997). Later, the destruction of the Republican Guard's combat outposts and reconnaissance elements limited the information transmitted to the Iraqi command, which resulted in the tactical surprise achieved by the 2ACR (Howlett, 2015). This lack of knowledge about the situation was tragic for the Tawakalna Division troops: when the Eagle Troop charged, many Iraqi tank crews were out of their armoured vehicles because they did not believe that they would be attacked at that moment, while others simply abandoned their vehicles when they heard the first explosions, thinking they were under air attack (Biddle, 1996).

The US troops had access to technology that provided them more detailed information. Satellite systems, such as JSTARS and SLAR (Lute, 1992), as well as remotely piloted aerial vehicles (Howlett, 2015) helped to clarify what was going on. Even so, at the decisive moment, the troops that engaged the enemy did not know his exact position, disposition and strength (McMaster, 2016), and commanders had to make decisions without crucial intelligence which would have allowed them to intervene more effectively. In fact, if the Eagle Troop commander had not taken the initiative to continue the attack, despite orders to halt at 70 Easting, the remnant forces of the Tawakalna Division might have been in a better position to retake the initiative and their counter-attacks might have been more organised and effective (Malouf, 2020).

Weather conditions were another important source of friction in the Battle of Easting 73. Heavy rainfall the night before made it more difficult for vehicles to move, especially those of the 1st Armoured Division, which delayed its forward passage of lines with the 2 ACR, while dense fog and sandstorms prevented the rotary-wing aircraft of the Dragoon Air Force from providing air support during most of the fighting (McMaster, 2016). In addition to this, there were winds of about 60 kilometres per hour. Much of the fighting took place under a combination of rain and sandstorms, which reduced the visibility of the battlefield to around 500 metres, and even to 100 metres on some occasions (Christenson & Zirkle, 1992). These conditions affected both sides, but did most damage to the Iraqis (Watts, 1995). The US had the advantage of having thermal vision systems in their vehicles, which gave them an average observation range of 1600 metres for the 2ACR's aiming systems during the battle, even in the worst operating conditions for that optical equipment. Experiments carried out in simulation systems found that if the US had not had thermal systems on that occasion, their losses would probably have gone from 2 to around 16 armoured vehicles, while Iraqi losses would have fallen from 86 to 60, which means that their importance cannot be underestimated (Biddle, 1996).

Even though the Iraqi tanks were switched off in the moments before the battle, and even after it had already began, due to the Iraqi forces' lack of information, the temperature variation from day to night helped to keep the metal of the vehicles warm even when the sand was cold, allowing them to be seen with thermal cameras (Barroso, 1996). Interestingly, Lute (1992) points out that if the visibility conditions had been better, the 2ACR might have seen that they were in the presence of a larger force and not have engaged decisively, simply fixing

the enemy and waiting for the 1st Armoured Division to arrive. This would have made them lose momentum and they would not have won such a resounding victory.

The superiority of the Abrams tanks in relation to the enemy's was another factor that hindered the Iraqi troops' manoeuvres. The machine-guns in defensive positions, such as the ones in the forward defence area of the village, could do nothing to stop the advance of armoured vehicles. The minefield that was emplaced next to the citadel was also ineffective. The vehicles' high manoeuvrability allowed them to avoid the explosives, and even when they did not, such as when the vehicle of the Eagle Troop operations officer triggered a mine, the damage was minimal. The inability to stop the advance of the 2ACR's tanks despite these defensive measures was a psychological shock to the Iraqi ground troops, paralysing them and leaving them in a state of panic (McMaster, 2016).

In addition, the Abrams' 120 mm calibre cannons had a longer range, by around 1000m, than the ones mounted on the T-72s, and were able to hit the Iraqi tanks before they could use their weapons. The depleted uranium ammunition penetrated both the sand berms and the armoured vehicles behind them, which meant that the obstructions installed by the Iraqi forces did little more than show the position of the vehicles and immobilise them (Howllet, 2015).

The 2ACR trained intensively for Operation Desert Storm, and it showed in its performance in the Battle of 73 Easting. A large part of their training took place in Germany, where they focused on combat against Soviet armoured vehicles. In addition, they arrived in the Middle East almost three months before the battle, which allowed them to familiarise themselves with the operational environment (Howllet, 2015). The tough, realistic training boosted the confidence of the US troops and gave them the ability to suppress their fear in the face of a numerically superior enemy and with the advantage of the defence, to the point that they felt as if they were conducting an exercise. Even so, at times, confusion was unavoidable. When engaging the enemy, the Eagle Troop's internal radio network became so overloaded that orders sometimes did not reach their destination (McMaster, 2016). If the tank commanders had not been properly trained to maintain the order of attack, the consequences could have been significant: in a simulation, if the regiment had broken formation during contact, this could have increased US losses from 2 to 25 armoured vehicles (Biddle, 1996).

The Abrams tanks gunners were highly efficient: 182 of the 215 shots fired by the crews struck their targets, at ranges of more than 2000 metres and in combat conditions. Interestingly, the first three enemy tanks that were destroyed were engaged by the same gunner in an interval of less than 10 seconds, which showed the quality of their training (Biddle, 1996). Eagle Troop's rate of fire was so high that the enemy was only able to fire two shots during the initial contact, and two more during the assault that followed. Thanks to correct fire distribution and control by the 2ACR platoon leaders, within a few minutes all the targets had been hit (McMaster, 2016).

The disparities in the training of commanders at all levels also affected the friction encountered by the troops at the Battle of 73 Easting. The US forces had prepared for massive

armoured combat against Soviet capabilities comparable to their own. Meanwhile, the Iraqis had trained and fought against Iranian troops (Howllet, 2015), who were less prepared and not as well equipped, with an intensity that was not nearly enough to prepare them for the coming assault. The training given to the 2ACR focused on rapid decision-making and on junior leaders taking initiative during armoured combat, allowing them a high degree of freedom for independent action (McMaster, 2016), while the Iraqi command structure continued to be rigid and centralised, limiting the troops' ability to adapt and respond to new situations (Howllet, 2015). Furthermore, despite being well-equipped, the soldiers of the Tawakalna Division were consistently unable to strike the US' armoured vehicles with their anti-tank weapons, and seldom used their artillery (Bourque, 1997).

4.3. Discussion

The types and elements of friction proposed by Clausewitz which played a relevant role in the armoured battle of 73 *Easting* were identified in the study findings and organised according to the classification by Ferreira, Ramos and Franchi (2018).

a. Contender: US

Type of effect: Technology (ownership)

Table 2 – Access to technology and friction on US troops in the Battle of 73 Easting.

Situation	Type of friction	Elements	Expected consequence	Relation to friction
Use of GPS	Information	Inaccuracy	Poor planning, estimating what is known, deducing the unknown	**Reduced**
Consequence: Having accurate location information obtained electronically reduced the amount of unknown data, and consequently the need to make deductions, increasing situational awareness and improving control.				
Access to technological intelligence gathering capabilities	Information	Inaccuracy	Poor planning, estimating what is known, deducing the unknown	**Reduced**
Consequence: Satellite systems and remotely piloted aircraft constantly provided accurate real-time intelligence to the US command, which made it easier for the 2ACR to plan rapid actions.				
Reduced visibility due to rain and sandstorms	Environment	Climate / Weather conditions	Uncertainties, delays	**Reduced**
Consequence: Despite the poor visibility conditions at various times during the battle, the US forces were able to use their weapons at long range thanks to the use of thermal vision equipment, reducing uncertainty about the enemy's movements and increasing firing efficiency.				
Vehicle manoeuvrability	Individual	Danger	Fear, hesitation	**Reduced**
Consequence: The enemy's machine-gun fire and even its anti-tank mines had little effect on the American vehicles, which were protected by heavy armour, reducing the soldiers' fear of executing the				

[Cont.]

Vehicle manoeuvrability	Individual	Physical exertion	Fatigue, exhaustion	**Reduced**
Consequence: The manoeuvrability of the 2ACR's vehicles made it easier to pass through the minefield; without it, this would have been slower and more time-consuming, exposing the crew to more fatigue.				
Use of special ammunition	Marches	Possibility of engaging the enemy	Planning how the reserves and fire support will be used	**Reduced**
Consequence: The Abrams tanks were equipped with depleted uranium ammunition that could penetrate the sand berms and the armour of the enemy cars simultaneously, reducing the need for indirect fire support; this made it possible to maintain the momentum of the attack.				

b. Contender: US

Type of effect: Technology (lack)

Table 3 – Lack of access to technology and friction on US troops in the Battle of 73 Easting.

Situation	Type of friction	Elements	Expected consequence	Relation to friction
Outdated topographical charts	Information	False	Poor planning	**Increased**
Consequence: The charts did not show the IPSA Pipeline road, which meant that it could not be used as a reference point to guide the troops during the advance.				
GPS signal failure	Environment	Climate / Weather conditions	Uncertainties, delays	**Increased**
Consequence: The poor weather conditions during the course of the fighting interfered with the US troops' GPS signal, creating uncertainty regarding the direction of the advance.				
Need to refuel	Marches	Lack of supplies and shelter	Disproportionate effort, fatigue, exhaustion, hunger, thirst, low morale	**Increased**
Consequence: A few hours after the start of the 2ACR was deployed on the eve of the battle, it had to stop to refuel, as US tanks have a high fuel consumption; this reduced the momentum of the attack, increased the troops' exposure to enemy attacks and reduced their readiness.				
Heavy rainfall	Marches	Bad roads	Delays	**Increased**
Consequence: The heavy rainfall the night before the assault made it difficult for the 1st Armoured Division's wheeled vehicles to manoeuvre, leading to a delay in the forward passage of lines. Tracked vehicles, such as the 2ACR's forward vehicles, were able to advance more easily.				
Dense fog, sandstorms, strong winds	Environment	Climate / Weather conditions	Uncertainties, delays	**Increased**
Consequence: The weather conditions led to uncertainty about whether it would be possible to use rotary-wing aircraft, hindering the support provided to the tanks on the ground.				

c. Contender: US

Type of effect: Training (efficient)

Table 4 – Efficient training and friction on US troops in the Battle of 73 Easting.

Situation	Type of friction	Elements	Expected consequence	Relation to friction
Use of ammunition to mark the zone of action	Environment	Terrain	Poor accessibility	**Reduced**
Consequence: Given the lack of clear landmarks on the terrain to delimit the zones of action during the engagement with the Iraqi forces, the US troops fired a missile and used the explosion to mark the firing sectors, improving the conditions to proceed with the manoeuvre.				
Simultaneous fire from tanks on first contact	Individual	Danger	Fear, hesitation	**Reduced**
Consequence: When they encountered the defensive outpost in the village, nine tanks from the Eagle Troop fired without hesitation, neutralising the enemy machine-gun positions before they could react.				
Effective long-range fire	Individual	Stress	Distorted view of the facts	**Reduced**
Consequence: The crews of the US tanks fired several shots at close to the maximum range of the main weapons, and at a high rate of fire, due to the efficiency of their training in selecting and engaging targets in stressful situations.				
Combat against a numerically superior enemy	Individual	Danger	Fear, hesitation	**Reduced**
Consequence: Despite engaging in combat with a numerically superior enemy, who had the advantage of defence, the 2ACR's attack was similar to its performance during exercises: it did not show any fear or hesitation in the face of danger.				
Problems with the information broadcast through the radio network	Individual	Stress	Distorted view of the facts	**Reduced**
Consequence: Even with the stress created by the absence of orders, which sometimes did not reach their destination due to congestion in the radio network, the vehicles remained in formation while carrying out the attack.				
Effective command	Individual	Danger	Fear, hesitation	**Reduced**
Consequence: The training of US commanders at all levels of helped them make decisions quickly and autonomously, and give orders when engaging with the enemy, thus avoiding the hesitation that can be detrimental in the high-speed, high-intensity fighting that occurs during a tank battle.				

d. Contender: Iraq

Type of effect: Technology (lack)d. Contendor: Iraque

Table 5 – Lack of access to technology and friction on Iraqi troops in the Battle of 73 Easting

Situation	Type of friction	Elements	Expected consequence	Relation to friction
Lack of knowledge regarding the use of GPS	Information	Inaccuracy	Poor planning, estimating what is known, deducing the unknown	**Increased**
Consequence: The Iraqis did not know that the US troops could use GPS to cross the desert, which led to flaws in their defence plans, as they believed that the attack would come from the area alongside the road.				
Lack of information about the enemy's approach	Information	Inaccuracy	Poor planning, estimating what is known, deducing the unknown	**Increased**
Consequence: Due to the lack of accurate sensors and the difficulty in the flow of information, the initial reports from Iraqi intelligence did not correctly inform the Iraqi forces of the strength of the attacking troops and they deduced (incorrectly) that it would not be the main attack.				

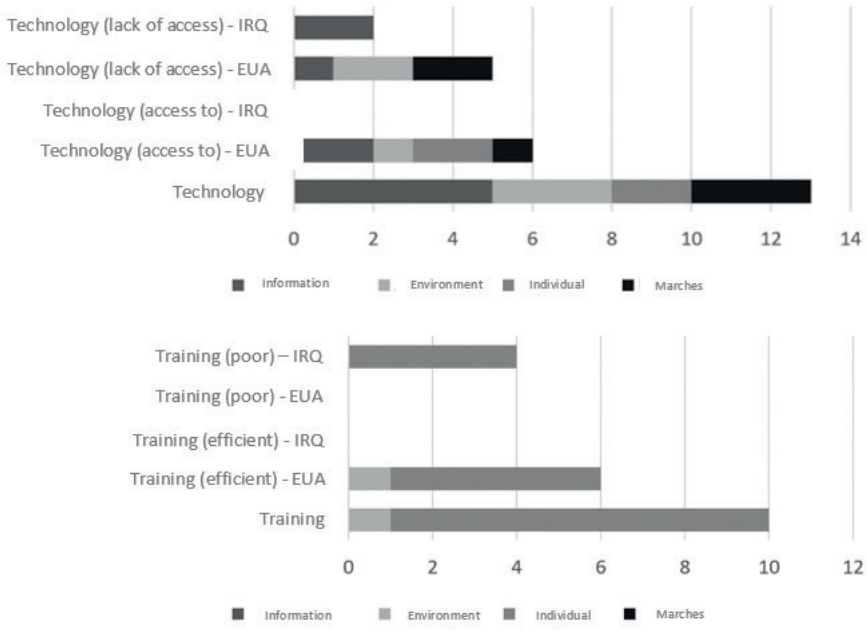
e. Contender: Iraq

Type of effect: Training (poor)

Table 6 – Poor training and friction on Iraqi troops in the Battle of 73 Easting

Situation	Type of friction	Elements	Expected consequence	Relation to friction
The tank crews were outside the vehicles when the attack began	Individual	Physical exertion/ Stress	Fatigue, exhaustion / Distorted view of the facts	**Increased**
Consequence: When the 2ACR engaged the Iraqi tank defences, their crews were outside the vehicles, resting in bunkers, or got out when they heard the first explosions because they thought it was an air attack.				
Rigid command structure	Individual	Danger	Fear, hesitation	**Increased**
Consequence: Iraq's rigid and centralised command structure limited its leaders' ability to make decisions, which resulted in fear and hesitation to take action during combat.				
High-intensity combat	Individual	Stress	Distorted view of the facts	**Increased**
Consequence: Iraqi troops had prepared to fight (and fought) other Arab forces, which did not have the same training as the US troops, and were overwhelmed by the intensity of the enemy actions, to which they were unable to adapt, and failed to respond to the challenge.				
Poor use of equipment	Individual	Danger	Fear, hesitation	**Increased**
Consequence: The Iraqis were not able to make the most of their equipment in real combat situations; they scarcely used their artillery and used their anti-tank weapons inefficiently.				

It was possible to infer from this data which types of friction the factors analysed here – technology and training – influenced the most.



Ghart 1 – Correlation of technology and training with different types of friction in the Battle of 73 Easting.

5. Conclusion

Armoured troops are decisive elements in combat (Brazil, 2019). Like the other components of an armed force, they can be affected by friction and their ability to achieve their objectives can be reduced, as proposed by Clausewitz (2010). To mitigate this problem, the study attempted to answer the following question: to what degree can training and technology influence friction during an engagement between armoured forces?

The data presented in the final section of the study shows that in the armoured combat that took place in the Battle of 73 Easting, access to more advanced technology reduced friction (6 cases identified in the US forces), while its absence increased it (5 cases in the US forces and 2 in the Iraqi forces). Furthermore, the quality of training reduced friction (6 cases in the US forces), while poor training increased it (4 cases in the Iraqi forces). This shows that, while technology had a greater effect on the information type of friction, the other types were also significantly influenced by it. On the other hand, training had more impact on the individual type of friction.

It should be emphasised that the relationship between technology and training vs. friction was only be considered relevant to the outcome of the conflict in relative terms. In other words, the superior technology and better training of one of the sides reduced the friction created by their actions in relation to the opponent's. In the case analysed here, this discrepancy gave the US forces an edge over the Iraqi forces. According to Biddle (1996), the mistakes by the Iraqi forces, which related to gaps in their training, created the opportunities for US technology to

make a difference; without this technological superiority, the mistakes would not have been sufficient to allow the 2ACR to have such an extraordinary outcome, with a historically low number of casualties.

Therefore, in a confrontation between enemies with similar technology and training, it is likely that both will face the same effects from the friction generated by those factors. This means that it is important to maintain high levels of proficiency in training, as well as in procuring innovative defence products, especially those that decide the outcomes of battles, such as armoured vehicles. Those who do not do this will engage in combat at a disadvantage and will have to overcome more obstacles in order to achieve victory.

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