Using Human Rational Behavior to Reconstruct Events of Scarce Archaeological Evidence

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Abstract

This paper demonstrates the application of Human Rational Behavior for the reconstruction of a series of five successive events bearing scarce archaeological evidence. The case analyzed here is the relationship between Egypt and the Arava during the 13th-10th centuries BCE. During this period, the copper produced in the Arava was a strategic and economically significant resource. The Egypt–Arava relationship is regarded here as a conflict of interest between two large producers of copper – Timna and Faynan – trying to maximize their revenues, and Egypt, a large consumer of this metal who wished to achieve a lasting supply at minimum price. To this end, the political situation, economic interests and possible strategies of each concerned party are analyzed along five specific periods of scarce evidence. The reconstruction achieved exhibits an expanded and enhanced understanding of the history along the entirety of the tested period.

Keywords: Behavioral archaeology, Behavioral ecology, Game Theory, Reconstruction

1. Introduction

The term **Human Rational Behavior (HRB)** used here needs some clarifications. HRB contains various aspects of the following disciplines: **behavioral archaeology**, **behavioral ecology** and **game theory**. As the boundaries between these methods are vague and highly controversial (Schiffer, 1999; Henshilwood and Marean, 2003) some relevant and simplified explanations are followed:

- **Behavioral archaeology** (BA) defined as the relationships between human conduct and material culture in all times and all places (Schiffer, 1976). Behavioral archaeologists are concerned with developing methods and theories for reconstructing and explaining past human conduct. BA was intended to replace cultural history and cultural reconstruction and to improve theoretical archaeology (O'Brien *et al.*, 1998).

- **Behavioral ecology** (BE) is the study of adaptive behavior in relation to social and environmental circumstances. It assumes that the strategies and decision-making capacities of humans are shaped by natural selection. Thus, BE is a subset of **evolutionary ecology** (Bird and O'Connell, 2006) and uses models drawn from optimization analysis and evolutionary **game theory** (Dugatkin and Reeve, 1998; Maynard, 1982). Codding and Bird (2015) view BE as a theoretical framework within archaeological science while Broughton and O'Connell (1999) foresee evolutionary ecology becoming the key to advancing investigations of human behavioral evolution.

- **Game theory** (GT) adds a social dimension to BE where the behavior of one individual depends on that of others (Bird and O'Connell, 2006). GT provides rational scenarios for a wide range of actual events in which actors ("players") make decisions with the intent of maximizing their interests (Hermans *et al.*, 2014). Thus, the GT provides a trans-disciplinary behavioral lexicon (Gintis, 2004) and offers a common method that can, potentially, unify the social sciences (Varoufakis, 2008). GT is widely used today in **economics** and politics. Alesina (1988) suggests models based upon the GT and **macro-economics**. Nonetheless, it is already understood that not every event is appropriate for examination under the GT, as described by Tuchman (1984) and de Bruin (2007).

This paper is also intended for scholars having limited background within the field of HRB. They are invited to learn more on the basic terms presented in Appendix A.

2. Prior conditions

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HRB is a modern term. Therefore, prior to any investigation, the following dilemmas should be raised and solved:

- Is it acceptable to compare the **cognitive behavior** of humans living during the Late Bronze Age (LBA) and Iron Age to modern ones?
- Is it justifiable to compare the recent **international economy** to the situation existing in the LBA and Iron Ages?
- What kind of **"legal"** means existed in the international market during these ancient periods which could satisfy both parties of the deal?

2.1. Cognitive behavior

Evidence presented by Henshilwood *et al.*, (2002) suggests that humans living at least as early as 35,000 years ago had cognitive abilities similar to that of modern humans. Schiffer and Skibo (1997: 40) described behavioral chains of activities according to which craftsmen of earlier periods operated: this includes the integration of technical choices within a process we might today call "trial and error". On the other hand, Henshilwood and Marean (2003) insist that there is no single paradigm – and there may never be one – for defining when, where, and how humans became behaviorally modern.

The first suggestion to combine archaeology with human behavior was made by Reid *et al.*, (1974). In the early 1970s, Schiffer (1972; 1975) presented his first vision for examining archaeology as a special behavioral science. It was assumed that within anthropology, only archaeology possesses the requisite time duration necessary for the study of long-term cultural change (Reid *et al.*, 1975). Later on, Schiffer's (1976; 1987; 1992; 1995; 1996; 1999) work went beyond explanations of artifact design and human behavior and expanded into history, social theory and evolutionary studies. Other researches broadened his work to include communication theory (Schiffer and Miller, 1999) as well as GT (Dugatkin and Reeve, 1998; Maynard, 1982). The latter achievements are most important for the following discussion.

Today, GT applies to a wide range of behavioral relationships, and is now a common term within the science of logical decision making (Guillermo, 2013; Harsanyi, 1977; Leinfellner and Kohler, 1998; Nash, 1951; Osborne and Rubinstein, 1994; Riker, 1978; Shapira 2008; Shubik, 1982; Weirich, 1998;). On the other hand, the use of GT in anthropology and archeology started very late and is still rare (Henrich *el al.*, 2001; 2004). Gezelius (2007) used GT to demonstrate how information sharing between fishermen could be used to interpret ethnographic data. Chattoe-Brown (2011) expanded Gezelius' work into sociology and concluded that GT and ethnography can be a very powerful combination, if used properly. Salgado *et al.* (2014: 325) used GT in an attempt to explain how natural selection leads to cooperation between competing individuals. Runciman (2005) combined archaeological evidence and GT in order to show how bands of hunters and foragers could cohere over many successive generations.

2.2. International trading in the LBA and Iron Ages

One of the basic requirements for having a functioning internal and international economy is defining the appropriate terms. Warburton (2010) shows that the ancient Egyptians used specific words for "to buy" (*jnj*), "to sell" (*rdj),* and "price", a word coincidentally identical to "silver" *(hd)*. Janssen (1975) and Zingarelli (2010) bring documents from Deir el-Medina, dated to the New Kingdom, in which copper (*debrn*) was the basic unit of value and pricing in Egypt. In addition, silver and grains were also used. The silver/copper ratio was 1:100 in the beginning of the New Kingdom and by the end of this era it fails to 1:60 (Warburton, 2010: 166). The fact that copper and silver appeared in the market is not surprising as both metals were part of the international market economy (Warburton 2010:170) during this era. Janssen (1975: 510-514) also shows evidence for transactions of expensive commodities thought written records. Some of the documents in the Amarna archive deal with such international relations (Hikade, 1998: 43). However, the amount of trade mentioned in EA was a small part of the national commercial level (Cappellini and Caramello, 2010: 52). Warburton sums his view on the Egyptian ancient economy by saying:

> Even the fragmentary evidence from ancient Egypt confirms the interlocking markets where prices resulting from general equilibrium were available. The fact that the copper and silver appearing in these transactions were themselves parts of the international market economy […] [and] international equilibrium prices […] confirming the general lines of Keynes's General Theory" (Warburton, 2010: 170, 173).

*2.3. The **"legal" means** in the old market*

Private-law documents were already known in Egypt from the period of the Egyptian Old Kingdom (Kokina, 2010: 89-92). On the other hand, international agreements were signed since the New Kingdom. The most famous of these were: the treaty signed after the Battle of Megiddo in 1480 BCE between Pharaoh Thutmose III and the king of Kadesh, and later, the agreement between Pharaoh Ramesses II and King Hattusili III of the Hittite Empire in 1258 BCE. Another set of treaties were achieved with nomadic peoples living along Egypt's western periphery. The Egyptians also had commercial treaties with major trading states in the eastern Mediterranean, such as the Cretans (Bederman, 2001: 147-150). The picture emerging from the archaeological evidence shows that copper used in pharaonic Egypt was tightly controlled and administered by the state (Rehren and Pusch 2012: 219). Therefore, when an agreement was not obeyed, the issue could be discussed directly between the two kings concerned. The Amarna Letters (e.g., EA 33, EA 34, EA 35) deal with such cases (Hikade, 1998: 43; Moran, 1992). EA 35 is an example of a correspondence between the king of Alashiya and the Pharaoh of Egypt in which the king of Alashiya apologizes for the low amount of 500 talent of copper he has sent. He also asks for a payment in silver for wood which had already been delivered from Alashiya.

To sum up: the three prior conditions are met, thus, the use of HRB is acceptable. Naturally, the decision makers during these antique eras were not familiar with terms such as Behavioral Archaeology, Behavioral Ecology and Game Theory; however, they were intelligent enough to understand how to maximize their interests (Runciman, 2005; Schiffer and Skibo, 1997, 40). Nobel Prize winner Aumann (1997: 4, 10) considers rational decisions as ones reached through "rules of the thumb". Also, in his view, no "rationality at all is required to arrive at Nash Equilibrium, insects and even flowers can and do arrive at Nash Equilibrium" (see Appendix A).

3. The problem of scarce evidence in Egypt and the Araba

When trying to characterize the archaeological evidence found in the Arava, especially from LBA and the Iron Ages, it is essential to quote the statement made by Ben-Yosef (2018: 210):

…although the region has been subjected to intense research since the late 1950s […] great caution is needed in the interpretation of analytical results based on archaeological evidence from the mining regions […] and it should be remembered that mining activities could have taken place without leaving any datable materials, such as organic remains suitable for radiocarbon dating or material-culture finds which can be dated based on typo-chronology.

The Egyptian's inscriptional evidence from Timna is very scarce. Most of them include royal names on small objects which were offered as votives gifts to the temple of Hathor. As much as 80 inscriptions were found in Sinai from the New Kingdom era. However, the information relates to the relationship between the Pharaoh and his officials (Hikade, 1998: 51). Detecting the provenance of the mined copper is also difficult: the wide spread in the lead isotope registers makes it very difficult to confidently pinpoint the specific source within the Sinai (Rademakers *et al.*, 2018a: 185). In addition, some of the bronze artefacts examined were produced from recycled materials which makes identifying their source very complicated (Rademakers *et al.*, 2018b: 518) or even impossible.

Most of the Egyptian copper sites can be dated to the Early Bronze (EB), Middle Bronze (MB) and LBA (i.e. Abdel-Motelib *et al.*, 2012: 50; Beit Arieh, 1981, 1985; Pfeiffer, 2009) while only few can be placed within the Iron Age. Rothenberg, (1970: 17) reports three smelting sites (Site numbers 350, 351, 352) operating from the 18th to the 15th Centuries BCE in Bir Nasb [Nasib]. These sites became active again only in the Nabataean, Roman, and Byzantine periods. Hikade (1998: 46) reports that the Egyptian activities in Wadi Nasib took place between Dynasties 12 and 19 while their next function was during the Nabataean period.

The information regarding the copper mines inside Egypt is limited. Lower Nubia began to smelt copper by the Old Kingdom or even earlier together with additional Egyptian copper sites in the northern part of the Eastern Desert. These sites are dated to the Late Prehistoric, Old Kingdom and Ptolemaic/Roman periods (Abdel-Motelib *et al.*, 2012: 50).

Rothenberg's (1999) excavations in Timna unearthed an Egyptian sanctuary and a main copper production site dated to the Egyptian New Kingdom. Yagel *et al.*, (2016: 14-16) assume that at the end of the 13th until the early 11th centuries BCE Timna was a part of a wider industrial establishment controlled by Egypt. Throughout this period the smelting activities in the Faynan area, ca. 100 km to the north of Timna, were slim. Some evidence of moderate

copper production was found only in the deepest layers of the excavations at Khirbat en-Nahas (KEN) Area M (Levy *et al.*, 2014: 815, 982).

The administrative policy of the Egyptians with the local workers was based on dividing up the labour into numerous different tasks and camps. Petrie (1906: 109–110) describes the various grades and functions of the men who were employed by them for the sake of "obtaining great results from small minds". Under these circumstances, the spreading or leaking of smelting knowhow to the locals is difficult to expect without the good will of the Egyptians.

At the end of Egyptian rule in Canaan, nearly every Egyptian base seems to have been torched (Morris, 2005: 709). In a huge contrast to the above, during the reign of Ramesses V (1145-1141 BCE), the last Ramesside pharaoh in Timna, the copper production sites in Serabit el-Khadim (Morris, 2005: 708) and Timna continued to function (Ben-Yosef *et al.*, 2012: 64). New smelting sites were founded in the Arava after the Egyptian withdrawal and copper production was increased (Ben-Yosef *et al.*, 2012: 64; Finkelstein, 2014: 93).

The supply of copper to Egypt was based on two sources: interior production and external trade. The main mines in the Eastern Desert, belonging to Egypt, were: Wadi Hammamat, Tura, Aswan, and in Sinai: Magharah, Serabit el Khadim, and Wadi Nasb (Cappellini and Caramello, 2010: 29). Cyprus possessed some of the richest copper mines in the world, especially in Apliki, where production took place from 1600 to 1050 BCE, reaching its peak in the 13th century BCE (Kassianidou, 2018). Most of the copper trade in the Eastern Mediterranean appears geologically to be of Cypriot origin (Rehren and Pusch, 2012: 220) and some of the production was sold to Egypt. Also, copper from Timna and Faynan reached Egypt, as will be discussed in the following. Smaller copper smelting sites were also located at Qurayyah and Tayma in the Arabian Peninsula. However, the Qurayyah site was active during the LBA while that of Tayma was dated to the Roman/Late Roman periods; thus, neither of them was operational during the Iron Age (Liu *et al.*, 2015: 492-495, Table 1).

An important research was performed into the Ramesside bronze production site in Qantir - Pi. This place offers rare insights into the secondary production of copper in ancient Egypt. The main question raised was: what are the sources of the materials that reached the site? Unfortunately, this question is still not complexly closed. The partial answers are: (i) fresh copper and tin after smelting, (ii) past copper stocks, and, (iii) re-melting of old bronze tools and weapons. Analysis made so far showed that most of the produced bronze in Qantir - Pi Ramesse was made from pure copper and tin (Rehren and Pusch, 2012: 215- 217). Rademakers (2017: 56, 57 Fig. 5) brings some uncertain evidence that may support the availability of Timna or Faynan copper in Pi Ramesse. On the other hand, Rehren and Pusch (2012: 220) claim that the "the dominance of Timna copper [at Qantir – Pi Ramesse] is not surprising". This huge difference in opinions demonstrates the uncertainty in the subject.

Summing up the situation of the copper industry in Egypt: at the end of the LBA, and contemporaneous with the cessation of copper production in Cyprus and in the Arabian Peninsula, Egypt withdrew from Timna. In addition, the replacement of bronze by iron in Egypt in the Iron Age was delayed until the second half of the first millennium BCE, much later than witnessed among other regional powers, thus, it is not surprising that the first large group of iron objects found in Egypt was dated to the 7th century BCE (Ogden, 2000: 167–168). In spite of all these circumstances, the inner production of Egypt in the Iron Age, far from the rates already achieved during the EB, MB or LB Ages (i.e., Abdel-Motelib *et al.*, 2012: 50; Beit Arieh, 1981, 1985; Pfeiffer, 2009). Some of this deficiency could be satisfied by re-melting old bronze products, though this alternative was possible only for a small part of the total production in Qantir - Pi Ramesse (Rehren and Pusch, 2012: 215- 217).

Anyhow, the re-melting of existing bronze or using existing stocks could not be considered long term solutions. We have no information regarding the reasons that caused the reduction of copper production. Nevertheless, it is apparent that by the Iron Age, the Egyptians had no shortage of the proper ore materials, since, in later eras such as the Nabataean, Roman, and Byzantine periods, an apex in copper production was once again reached.

An excellent example for the difference in investments spent in the Iron Age compared to the Old Kingdom is demonstrated in the smelting site of Seh Nasb, located in the south-western part of the Sinai Peninsula. At this site, a massive installation of 27 batteries of furnaces providing for 3000 copper smelting units were built (Tallet *et al.*, 2011). No such investment in the copper industry was ever witnesses in Egypt in later periods.

4. Results and discussion

4.1. Preface

It is assumed that the main conflicts between the Arava and Egypt were related to copper costs, quantities and delivery time. The Arava aimed at maximizing its revenues and maintaining its sovereignty, while Egypt wished to achieve a lasting commitment of copper at minimum price. Along the tested periods, the geopolitics, interests and strategies of the two parties changed. Therefore, a separate analysis will be performed for each of the tested eras. The periods selected for analysis are: (i) along LBA, (ii) the end of LBA, (iii) the early Iron Age I, (iv) the middle of the Iron Age I, and, (v) the Sheshonq I campaign, ca. 925 BCE. In each of the analyzed periods, the following issues will be examined: (i) the specific parties to the conflict, (ii) the objectives, strategies and the resultant equilibrium achieved in the event, (iii) the consistency of the HRB result with existing archaeological evidence, and (iv) the contribution of the HRB outcomes for enhancing our understanding of the event.

4.2. Analysis of the Late Bronze Age (LBA)

In LBA, Timna was a part of an industrial establishment controlled by Egypt (Yagel *et al.*, 2016: 14-16); thus, it cannot be considered a direct active player in this scenario. Thus, the participants engaged in this event are Egypt and Faynan alone, with Faynan being considered an independent manufacturer engaging with the Egyptian market, while a few smaller sites (Avner *et al.*, 2018), relying on inferior technology (Shilstein and Shalev, 2018: 239), can be ignored.

The objectives, strategies and their resulting equilibria are shown in Table 1. Scenario 1 assumes that the Egyptians were considering merging Faynan with Timna for the sake of increasing the internal Egyptian copper production rather than purchasing copper from the external market. If Egypt succeeds, it would be a "Win" situation: the internal Egyptian production would increase; however, if Faynan refuses, Egypt may need military action to support such an act.

On the other hand, such a merger may end with a "Lose" for Faynan: its independence would end and its revenues might be damaged as the Egyptian-proposed incentives may not compensate for its economic losses. Therefore, Faynan has a better option, i.e. to preserve its production and independence. Thus, Nash Equilibrium will not be reached as this scenario will end in a "Win/Lose" situation. Scenario 2 is much more positive: as Egypt exploits only a small part of Timna, the mining and the smelting activities might be further expanded without the inclusion of Faynan and without the need to use force. In these circumstances, the two parties will decide to ignore each other and then a Win/Win and Nash Equilibrium are reached, and evidently, this scenario is preferred.

Scenario	The Party	Objectives	Strategy	Expected Outcome	WIN/LOSE	Nash equilibrium
1	**Egypt**	Reduction of inner copper shortage by adding a new supplier	Offering economic incentives to Faynan	(i) Faynan finds the Egyptian offer unacceptable (ii) Egypt may need military force to enforce its proposal	WIN/LOSE	Not attained
	Faynan	(i) Increasing its revenues. (ii) Preserving its sovereignty	"Listen and consider"			
2	**Egypt**	Reduction of Egyptian copper shortage	"Ignores Faynan"	Expanding the production at Timna itself	**WIN/WIN**	**Attained**
	Faynan	(i) Increasing its revenues. (ii) Preserving its sovereignty	"Ignores Egypt"	Preserves its existing situation throughout the LBA		

Table 1: The objectives, strategies and the equilibria achieved during the LBA

This theoretical solution is consistent with the archaeological data: no signs of an Egyptian presence were found in Faynan during LBA (Levy *et al.*, 2014, 815, 982). Such an outcome might be supported by sample 1987-0512 (Rademakers *et al.*, 2017: 56), which equally matches both Timna and Faynan. Also, Yahalom-Mack *et al.*, (2014: 175) conclude that Faynan replaced Cyprus as a major player in the eastern Mediterranean trade.

The above archaeological outcomes demonstrate how scarce archaeological results can be supported (or, alternatively, unsupported) by addressing the simple concepts of "benefit" and "alternative option selection", both inherent functions within GT.

4.3. Analysis at the end of LBA

The end of Egyptian rule in Canaan was short and bloody: nearly every Egyptian base in this area seems to have been torched, either by enemy attackers, by garrison uprisings, or by the Egyptians themselves as they retreated (Morris, 2005: 709). However, during the reign of Ramesses V (1145-1141 BCE) the copper production sites in Serabit, Sinai (Morris, 2005: 708) and in Timna continued to function (Ben-Yosef *et al.*, 2012: 64).

The participants engaged in this conflict are Egypt and Timna. At this stage Faynan is an independent entity. The objectives, the strategies and the resultant equilibria achieved in this event are shown in Table 2. The basic objectives of Timna are: (i) to acquire the Egyptians' copper technology and production practices (Petrie, 1906: 109–110), (ii) to prevent Egypt from destroying Timna (Morris, 2005: 709), and (iii) to establish a captive copper market with Egypt. Timna understands that receiving the technologies while keeping the site unharmed is a great economic advantage and is ready to offer a long term supply agreement with Egypt in return.

Egypt intends to retreat from the area and knows that it internal copper demands are not being met by its inner production alone (Abdel-Motelib *et al.*, 2012: 50), and thus wants to safeguard its internal needs through external sources. Achieving this goal could be fulfilled only by keeping the Timna site undamaged and transferring its copper technology to the locals.

Scenario 1 shows that there is no a real alternative for either of the two players other than a deep cooperation: if no understanding is reached, the Egyptians may destroy Timna without transferring their knowhow. As a result, the Arava would have problems continuing production successfully. Thus, as Timna is an important source of copper, Egypt would fail to satisfy its inner copper supply. Therefore this scenario ends in a "Lose/Lose".

Scenario	The Party	Objectives	Strategy	Expected Outcome	WIN/LOSE	Nash equilibrium
1	Egypt	Weakening its future enemies	(i) "obtaining great results from small minds" (ii) Scorched earth	(i) Egypt destroys Timna and does not release the knowhow (ii) Timna faces difficulties in running the site. (iii) The copper shortage in Egypt increases	LOSE/LOSE	Not attained
	Timna	Preventing the site from being destroyed and receiving the knowhow and the operation procedures	(i) Proposing a long term supply agreement at preferred conditions (ii) Possibility of industrial espionage			
2	Egypt	securing its future copper demands	Technological transfer and guiding the locals in the practices	(i) Reaching a mutual agreement for a long-term copper supply (ii) Timna is able to continue running the site	**WIN/WIN**	**Attained**
	Timna	Preventing the site from being destroyed and receiving the knowhow and operation procedures	Proposing a long term supply agreement at preferred conditions			

Table 2: The objectives, strategies and the equilibria outcomes at the end of LBA

On the other hand, a mutual agreement will lead to Win/Win situation and Nash Equilibrium as shown in Scenario 2. It should be noted that there was a tremendous development in international law and an increase in international treaties during the LBA (Bederman, 2001: 147-150; Breasted, 200: 163-174; Hikade 1998: 43; Moran 1992). However, no record of such an agreement related to Egypt-Timna relations has yet been found. Thus, based on HRB principles it is possible to suggest the assumed terms of their agreement: Timna was obliged to a long term supply at a preferred cost, and in return, Egypt transferred its knowhow and withdrew peacefully. This is supported by the field evidence: after the withdrawal of the Egyptians from Canaan, ordinary copper production continued (Morris, 2005: 708) while new smelting sites were founded in the Arava and the overall copper production increased (Ben-Yosef *et al.*, 2012: 64; Finkelstein, 2014: 93).

This discussion demonstrates: (i) the scarce archaeological evidence supports the outcomes attained through completely different methodologies (i.e. economic, rational and geopolitical considerations), (ii) the combined narrative reached from both the archaeological and GT methods provides an expanded and enhanced understanding of the event: the peaceful withdrawal of the Egyptians and the ability of the locals to continue full and independent copper production are a result of a commercial agreement in which Egypt agrees to transfer its knowhow in return for Timna continuing to supply copper to Egypt, and

(iii) the necessity of the Arava to increase production stems from its need to comply with the agreement with Egypt, and, later, to satisfy additional international markets (Finkelstein and Lipschits, 2011; Homès-Fredericq, 1992; Lev-Tov *et al.*, 2011) in order to further increase its revenues.

4.4. Analysis at the beginning of the Iron Age I

The participants engaged in this conflict are Timna and Faynan. After the Egyptians withdrew from Canaan, Timna and Faynan became two independent copper manufacturers. This situation is called today **oligopoly,** defined as a small number of producers controlling a market but lacking the ability to prevent competition. Therefore, it is characterized by moderate price increases due to the competition. At first, the two competitors, Timna and Faynan, continue to work separately. This situation will lead to a decrease in their integrated revenues. Then, at a certain time, they presumably decide to negotiate for a better market tactics. The strategies of the players and the equilibria reached are shown in Table 3.

The top three scenarios are presented. Scenario 1 and Scenario 2 assume a situation in which one party wishes to establish the consortium but the other wants to maintain its sovereignty while willing to comply with certain acts for the sake of reducing mutual competition (i.e., splitting the market on a geographic bases, or price coordination). Such proposed acts would likely be difficult to monitor and very easy to override. The first two scenarios fail to be Win/Win or stable because these acts are secondary and have no effect on one essential issue: improving the operating efficiencies in both sites by merging the technical and managerial efforts. This option, described in Scenario 3, sees both parties merging into a consortium after a mutual agreeing to make revenue as their top priority. In order to understand the real economic situation of the Arava, the global circumstances should be described: (i) the copper industry of Egypt is slim (Abdel-Motelib *et al.*, 2012: 50), (ii) Cyprus (Kassianidou, 2018) and Arabia (Liu *et al.*, 2015: 492-495, Table 1) have halted production, and, (iii) the Aegean and Eastern Mediterranean Seas were closed for international ties as a result of the Sea Peoples' raids (Kaniewski el al., 2015: 2). Therefore, the consortium is actually a **monopoly,** defined as a single entity dominating the sale of a certain product and having the privilege of changing its prices easily.

This final situation is a Win/Win and stable, and thus is the preferred scenario for Timna and Faynan but it is the most un-favorable situation for the customers. The copper monopoly opened new markets with the northern countries via the King's Highway. This caused Moab to establish lines of fortresses along her Eastern border (Homès-Fredericq, 1992; Finkelstein and Lipschits, 2011; Lev-Tov *et al.*, 2011). Recent evidence demonstrates that the markets extended as far as Olympia and other Aegean destinations from 950 to 750 BCE (Kiderlen *et al.*, 2016). At the same time, the Arava consortium succeeded through a gradual technological evolution to achieve an enormous technical revolution in copper production technology (Luria, 2016: 55-70) and became the greatest producer of copper in the Levant (Ben –Yosef, 2010).

The consistency of the HRB solution with the archaeological evidence can be demonstrated in a few examples: (i) a comparison between technological results from Faynan and Timna shows similar characteristics; the residual copper content in the slag from Timna 30 and Khirbat al-Jariya at Faynan were 1.55±0.93% and 1.58±0.93%, respectively (Ben Yosef *et al.*, 2019: 4), (ii) the smelting in both sites was centralized at the same time (Levy *et al.*, 2014), (iii) the new technological improvement ("Production System 3") was started in Faynan and in Timna at the same time, at ca. 925 BCE (Ben Yosef *et al.*, 2019: 9).

The most important contribution of the above analysis in enhancing our understanding of the events is the outcome regarding the establishment of a monopoly in the beginning of Iron Age I. This event changes the market from being an **oligopoly**, with moderate price changes, to a **monopoly**, where prices can be changed much more easily. This action enormously affected the future international copper trade, as will be shown in the following.

In this regard, it should be added that the terms "monopoly" or "oligopoly" did not exist during the Iron Ages, but their economic meaning should have been clear to rational and commercial thinkers.

Scenario	The Party	Objectives	Strategy	Expected Outcome	WIN/LOSE	Nash equilibrium
1	**Timna**	Revenue increase	Establishing a consortium	(i) implementations for eliminating competition found difficult to comply with and to monitor (ii) Merging technical and managerial efforts are not achieved (ii) Revenues are not maximized and competition continues.	LOSE/LOSE	Not attained
	Faynan	Preserving mutual sovereignty while eliminating competition (*i.e.*, splitting the market, price coordination)	Accepting small modifications to the existing situation			
2	**Faynan**	Revenue increase	Establishing a consortium		LOSE/LOSE	Not attained
	Timna	Preserving mutual sovereignty while eliminating competition (*i.e.*, splitting the market, price coordination)	Accepting small modifications to the existing situation			
3	**Faynan** **Timna**	Revenue increase is the preferred objective.	Establishing a consortium	(i) A monopoly is established. (ii)The integrated revenues increase	**WIN/WIN**	**Attained**

Table 3: The objectives, strategies and the equilibria achieved for Timna-Faynan in the beginning of Iron Age I

5.5. Analysis at the middle of the Iron Age I

In this event the participants engaged are Egypt and the Timna-Faynan monopoly. It was assumed earlier that at the end of LBA, Timna and Egypt reached a long term agreement for copper supply. At that time, the monopoly had not yet been established. In principle, the new consortium might continue to comply with Timna's original obligations to Egypt; on the other hand, a monopoly is usually focused on maximizing revenues, which would abide by the opposite strategy. Therefore, both possible scenarios are tested. The strategies of the players and the final equilibria reached are shown in Table 4.

Scenario	The Party	Objectives	Strategy	Expected Outcome	WIN/LOSE	Nash equilibrium
1	**Monopoly**	Keeping good relations with Egypt	Comply with the original agreement established by Timna in the LBA	Monopoly's revenues are not maximized	LOSE/WIN	Not attained
	Egypt	To continue abiding by the agreement with Timna made in the LBA	A diplomatic appeal			
2	**Monopoly**	Maximizing revenues	Increases copper price	(i) Egypt rejects the increased price (ii) The monopoly	LOSE/LOSE	Not attained
	Egypt	To continue	A diplomatic protest			

		abiding by the agreement with Timna made in the LBA	while lacking the ability to reinforce its demand	insists on its offer (iii) The monopoly loses a captive market		
3	**Monopoly**	Maximizing its revenues	Increase copper price gradually and moderately	(i) Egypt obliges to some price rise as it lacks a better option (ii) Monopoly's revenue increases	WIN/WIN	Attained
	Egypt	To continue abiding by the agreement with Timna made in the LBA	A diplomatic protest while lacking the ability to reinforce its demand			

Table 4: The objectives, strategies and equilibria achieved between Egypt and the Timna-Faynan monopoly in the middle of the Iron Age I

In the middle of the Iron Age I, Egypt is still militarily weak and cannot threaten its neighbors. At the same time, the Arava is flourishing. Three grand scenarios describe the main options available to the parties. Scenario 1 presents a situation where Egypt appeals to the Timna-Faynan consortium to abide in full compliance with the obligations originally established with Timna in the LBA, and the monopoly agrees. The result is not stable, as the monopoly can take advantage of Egypt's weaknesses and to increase its revenues. In Scenario 2, the monopoly insists on its high prices but Egypt rejects it. In the extreme case, Egypt cannot withstand such high expenditures and, as a result, stops purchasing copper. If this happens, the consortium loses Egypt as a captive market. This episode finishes as a Lose/Lose situation. However, both parties still have a preferred option, described in the compromising situation of Scenario 3: the monopoly suggests a moderate and gradual price increase. Egypt is also ready to accept this, as it does not have a better option – thus a Win/Win and Nash Equilibrium are met.

The advantage of the HRB method in analyzing this event is its ability to explain the commercial conflict between the Arava and Egypt as a result of: (i) a market change from oligopoly to monopoly, (ii) the slow withdrawal of the Arava from its agreement made at the end of LBA, and due to (iii) the failure of the Egyptians to re-develop their own abundant copper sources. This inability may be attributed to lack of either technical or managerial skills.

4.6. Analysis for Sheshonq I's campaign

As the deficiency in copper became more critical in the second half of the 10th century BCE and as Egypt regained its military power, Sheshonq I decided to remediate this shortage. The sole candidate able to address this problem was the Arava (Fantalkin and Finkelstein, 2006: 27). This campaign to Canaan was launched in ca. 925 BCE.

Scenario	The Party	Objectives	Strategy	Expected Outcome	WIN/LOSE	Nash Equilibrium
1	**Egypt**	Egypt: Securing inner copper demands and reducing its cost	An aggressive diplomacy: capture the Arava by force and taking over production from the locals	(i) Egypt succeeds easily to conquer the Arava. (ii) Egypt fails to operate production successfully. (iii) The shortage of copper in Egypt worsens (iv) Arava monopoly stops existing	LOSE/LOSE	Not attained
	Arava		Non-aggressive diplomacy: withholding technical, managerial and manufacturing assistance from Egypt by a peaceful evacuation of all workers from the sites			
2	**Egypt**	Arava: Increasing their revenues and preserving its sovereignty	"Talking business while holding a big stick": i.e., proposing economic incentives and threatening military activity	(i) Egypt conquers the Arava and takes over production, but lacks the skill to operate the sites (iii) The shortage of copper in Egypt worsens (iv) Arava monopoly stops existing	LOSE/LOSE	Not attained
	Arava		Arrogant refusal diplomacy: "Egypt has no other alternative to our copper and will be obliged to abide by our terms"			
3	**Egypt**		"Talking business while holding a big stick": i.e., proposing economic incentives and threatening military activity	(i)The Arava accepts the Egyptian terms (ii) Egypt accepts the Arava's terms (iii) The Arava increases copper production and maintains its sovereignty	**WIN/WIN**	**Attained**
	Arava		Non-aggressive diplomacy: withholding technical, managerial and manufacturing assistance from Egypt by a peaceful evacuation of all workers from the sit			

Table 5: The objectives, strategies and equilibria achieved between Egypt and the Timna-Faynan monopoly

Sheshonq I brings a new tiebreaker into the arena – a military campaign demonstrating Egypt's newfound military strength and ability to once again secure its global position and to demand better economic terms. The participants engaged in this event are Egypt and the monopoly of Timna-Faynan. The strategies of the players and the equilibria reached are shown in Table 5 which shows the three top scenarios of the two players. Scenario 1 assumes Egypt takes over the Arava by force. From the point of view of a military operation, it is a simple act. Nevertheless, the Egyptians should realize that this deed can end with catastrophic results, because: (i) they are not skilled enough to run the large copper sites in the Arava successfully, as was demonstrated in their failure to operate their local production sites, (ii) taking the Arava by force may lead to the loss of the advanced technology and the excellent management already established by the locals (Luria, 2016: 55-70), and, (iii) a confrontation with the Arava would cause a serious interruption in the ordinary copper supply while Egypt has no replacement for this loss.

The Arava understands that they have no chance to react by force. However they can assume that their high technological skill and their strong economic position allow them to demand that they will continue to operate and manage the copper sites while maintaining their political sovereignty. Thus, the Arava prefers a non-aggressive resistance strategy, namely, if worse comes to worst: (i) prevent Egypt from gaining the Arava's advanced technical and managerial information, and, at the same time, (ii) prevent any manufacturing assistance from the local workers. In order to accomplish these objectives Timna and Faynan are ready to vacate their specialist craftsmen as well as the simple workers from the sites prior to the Egyptians arrival – without harming any of their facilities. This would be a relatively simple act to perform by a nation of nomads.

In these circumstances, the quick "victory" of taking over the sites would result in a complete Egyptian failure: they would not be able to manufacture copper, or at least the production would be very limited. Alternatively, if the Egyptians decide to destroy the Arava's facilities, they would find that Egypt itself would be the first to be harmed as a result of this deed. Thus, Scenario 1 ends in a Lose/Lose that no party wants. Scenario 2 assumes that the Egyptians understand the limitations of force. Therefore Egypt tries the strategy of "talking business while holding a big stick", i.e., threatening their rivals with their military, while suggesting realistic business proposals that the Arava could accept. On the other hand the Arava practices an arrogant refusal diplomacy that assumes that Egypt has no better alternative but to accept the monopoly's terms. As Egypt cannot accept such insulting conditions and wants to threaten other potential rivals, it might take revenge and destroy the copper sites. Obviously, this scenario also ends in a Lose/Lose situation which both parties would like to prevent.

Scenario 3 presents the preferred option, in which both players decide to compromise. Egypt threatens the Arava with its forces. To this end, Egypt does not need to march their army all the way to the copper sites, but can demonstrate their presence from a nearby position in the Negev desert. In addition to its military posturing, Egypt offers the monopoly acceptable commercial proposals. On the other hand, the Arava continues acting according to a non-aggressive diplomatic policy while threatening the Egyptians with the option of evacuating of all of the local workers from the sites and at the same time negotiating the terms of the agreement. This scenario ends with a Win/Win situation and Nash Equilibrium.

An event recorded in the Bible from this same campaign of Sheshonq I supports Scenario 3: the conflict between Sheshonq I against Rehoboam (1 Kings, 14: 25-26) in which the treasures of the king's house in Jerusalem were looted without entering into a military confrontation. In return, Sheshonq I agreed not to attack the city. In both cases neither Jerusalem nor Faynan or Timna were mentioned in the Sheshonq I list.

An interesting outcome of this analysis is that a direct military intervention of Egypt would, most likely, damage its inherent interests. It seems that the single advantage of the Egyptian's military forces is its ability to threaten their opponents with their potential destructive capabilities. This "rational" result contradicts the "intuitive" conclusion that a military intervention took place, such as expressed by Levy et al., (2014: 984) with regards to Faynan. A more realistic option is described by Fantalkin and Finkelstein (2006: 27), who assume that the objective of Sheshonq I's campaign to Canaan was to preserve and to promote the copper industry in the KEN (Faynan) – Tel Masos system. As a result, the Arabah copper industry underwent a major re-organization (Ben-Yosef and Sergi, 2018: 462) and a technological leap in copper technology was achieved (Ben-Yosef et al., 2019: 11).

Sheshonq I's campaign succeeded in redefining Egypt's dominant status in Canaan and in achieving its specific commercial objectives. After re-achieving its strong position, Egypt established a new strategy intended to preserve their interests in Canaan, remotely, through "low profile diplomacy".

This policy was carried out by allowing the continuation of Canaanite sovereignty while preserving the option of an additional military intervention. This policy is supported by archaeological evidence found within the geographic regions mentioned in Sheshonq's I topographic list (Finkelstein, 2014: 98; Ben-Dor, 2015: 17-18).

5. Conclusion and perspectives

This paper presents a simple and a practical procedure for achieving historical reconstructions in cases of scarce archaeological evidence. The outcomes of its analysis clarify and expand our understanding of some "hidden events" between Egypt, Timna and Faynan during 13th-10th centuries BCE. This was performed through an examination of the objectives and strategies of each party along five successive and separate events, determining for each event, the preferred scenario that would satisfy, as far as possible, all concerned parties.

The advantages of the HRB analysis over more traditional archaeological methods can be demonstrated in two aspects. The first is the advantage of HRB to expose "hidden" episodes: one such case demonstrated here being the market change, from an **oligopoly**, with moderate price changes, to a **monopoly**, where prices could be changed much more easily. This event is totally absent from the traditional archaeological picture, although this fact had a significantly important role on the future international copper market. The second advantage of HRB is its potential to expose and to exclude the limitations of intuition. Using HRB analysis could demonstrate how the use of a direct military force by Sheshonq I against the Arava would have jeopardized the inherent interests of Egypt. This option is also supported by Kitchen (1986: 296–297) from an archaeological point of view. On the other hand Levy *et al.* (2014, 984) supported the intuitive narrative of a military intervention.

The HRB analysis was carried out exclusively and independently on the basis of human rational and economic considerations, while, the archaeological evidence came, merely, from field excavations. The resulting integrative narrative produced from both disciplines provides an enhanced and broadened understanding of the period.

The kind of subject tested here is by no means unique in the archaeology. Nevertheless, at this stage, the integration of archaeology, human rational, national politics, and economic considerations is very limited. It is hoped that this paper will encourage more inter-disciplinary works.

Appendix A: Relevant terms in HRB

This paper is also intended to encourage scholars having only limited background in the field of Human Rational Behavior (HRB). To this end, a short and simplified explanation of basic terms is presented.

The objective of this paper is to present a simple and a practical procedure for performing HRB analysis in cases of scarce evidence. The desire for simplicity requires the use of limited and clear terms:

(A.1) A **Win/Win** situation exists when both parties of a conflict end their dispute having achieved a beneficial outcome. A **Lose/Lose** situation is the opposite case. A conflict can also end in a **Win/Lose** or **Lose/Win** situation, in which only one party is satisfied (Burgess and Burgess, 1977: 306). Situations of **Lose/Lose** and **Win/Lose** would not be stable, and as such, are not preferred outcomes for a conflict.

(A.2) The **benefit** (i.e., revenue increase) can be expressed in terms of **positive-sum**, in which the total gains and losses of all the participants is greater than zero (Burgess and Burgess, 1977: 309). This situation will occur in instances of distributive bargaining where different interests are negotiated so that everyone's needs are met as closely as possible. In contrast, the zero-sum game refers to situations in which the total of wins and losses adds up to zero (i.e., poker and gambling).

(A.3) A classic game must be either **cooperative** (i.e., the parties are known to each other before the game and are permitted to negotiate with each other), or, vice versa, **non cooperative** (Harsanyi, 1977: 6-7; Osborne and Rubinstein, 1994: 2). In our case, the cooperative situation will be the dominant case as, by the Late Bronze (LBA) and the Iron Ages, the Arava and Egypt had cooperated with each other and were aware of the strengths, weaknesses, and interests of the other.

(A.4) Nash Equilibrium is a major term in GT. This situation is reached when no player has anything to gain by changing his strategy as long as the other players keep their strategies unchanged (Osborne and Rubinstein, 1994). Thus, a Nash Equilibrium is a stable situation**.** The classic GT assumes that players choose strategies simultaneously; however, in real-world situations, the games start at a state of status quo.

Following Brams (2011) methodology, it will be assumed here that at certain time, one player decides to depart from the status quo, and adopts a long-term strategic objective(s) to improve his standing. Thereafter, the second player has to react, carefully taking into consideration his best option for addressing the new situation.

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