A Counterfactual Study of the Charge of the Light Brigade[1]

David Connors
Department of History
dc03mh@brocku.ca

Michael J. Armstrong, Associate Professor
Department of Finance, Operations, and Information Systems
michael.armstrong@brocku.ca
905-688-5550 x 5323

John Bonnett, Associate Professor
Department of History
jbonnett@brocku.ca
905-688-5550 x 5552

Brock University, 500 Glenridge Avenue, St Catharines, ON, L2S 3A1, Canada

Abstract

We use a mathematical model to perform a counterfactual study of the 1854 Charge of the Light Brigade. We first calibrate the model with historical data so that it reproduces the actual charge's outcome. We then adjust the model to see how that outcome might have changed if the Heavy Brigade had joined the charge, and/or if the charge had targeted the Russian forces on the heights instead of those in the valley. The results suggest that all of the counterfactual attacks would have led to heavier British casualties. However, a charge by both brigades along the valley might plausibly have yielded a British victory.

Keywords

Counterfactual, simulation, military history, Crimean War, salvo model

Introduction

The Crimean War of 1853 to 1856 began as just one of a series of regional conflicts between Russian and its neighboring states, but it grew much larger due to the intervention of Britain and France (Kagan 2002: 132). The most iconic event from this war was the Charge of the Light Brigade, which took place during the Battle of Balaclava on 25 October 1854. On that day, British cavalry advanced under heavy cannon fire "through the valley of death" in a costly and futile attack against the Russian positions.

Debate over this bloody charge began almost before the horsemen had finished retreating (Hibbert 1961). Much of the discussion has speculated how the battle might have turned-out if the British leaders had issued or interpreted their orders differently. What if the cavalry had charged a hilltop redoubt, as the army commander Lord Raglan claimed was his intent, instead of along the valley? What if Sir James Scarlett's Heavy Brigade had joined in the charge, as the division commander Lord Lucan had initially ordered and as the Light Brigade commander Lord Cardigan had expected? Could either of these alternatives have materially improved the British outcome, or would Raglan's orders have led to disaster no matter how they were executed (Ponting 2004: 142)?

The debate has been fueled in part by the battle's importance to the Crimean War, and thus its implications for post-war Europe. As actually fought, the battle was only a minor Russian success. But if Russia had won decisively and recaptured Balaclava, it would have forced Britain to abandon the siege of Sevastopol, and undermined the entire allied campaign (Royle 2004: 265-267). Conversely, a decisive Russian defeat at Balaclava might have discouraged their later attack at Inkerman and enabled a faster resolution of the siege and the war.

The purpose of this paper is to examine whether a plausible change in the conduct of the British cavalry charge at Balaclava could have significantly altered the outcome of the charge, and hence the battle. To give this counterfactual study some quantitative substance, we construct a mathematical model of the charge. Drawing on historical sources for our data inputs, we calibrate the model so that its outputs initially reflect the Light Brigade's actual charge along the valley. This provides an historical baseline for the study.

We than adjust the model's inputs to represent three counterfactual scenarios relating to the orders made and interpreted by the British leaders. The first counterfactual supposes that the Heavy Brigade accompanies the Light Brigade in a joint charge against the Russian cannon at the east end of the valley. The second instead assumes that the Light Brigade charges the Russian cannon on the heights south of the valley. The third studies a joint charge by the two brigades against the heights.

The modeling results provide quantitative support for four tentative conclusions. First, the historical charge had no meaningful chance of success. Even if the British cavalry had been considerably "luckier", their attack as actually delivered would still have been bloody and unsuccessful. Second, British losses would have been even higher if the Light Brigade had been joined by the Heavy, and/or if the cavalry had charged up the heights rather than along the valley. Third, Raglan's intended charge against the heights would likely have given worse results than the one Lucan actually carried out. Fourth, a combined charge by both brigades along the valley would have offered the British their best chance of a meaningful, though costly, victory.

We believe this research makes a contribution to a pair of overlapping historical debates related to the battle. One is the military question about whether the battle could have turned out

differently if the British leaders had made different tactical decisions. Could the British have won decisively, or lost badly, and thereby influenced the progress of the war? The other concerns the accusations made by those leaders after the charge regarding who was to blame for its bloody failure. Who was "right" and who was "wrong"?

This study also contributes by demonstrating a novel mathematical approach to modeling battles that involve distinct impulses of combat power and casualties. We hope that historians will adapt the model to study other engagements of this nature, such as those involving cavalry charges, airstrikes, torpedo spreads, or missile salvos.

The Charge and its Context

The goal of the British-French-Turkish invasion of Crimea was the capture of the fortified Russian naval base at Sevastopol. After landing on the coast north of the city, the Allies had defeated the Russian field army at the Battle of Alma and then marched south to lay siege to Sevastopol. The seizure of that city would eliminate the Russian naval presence in the Black Sea, and thereby restrict its ability to attack Turkey.

During the prolonged siege, British supplies had to be unloaded in nearby Balaclava harbor, and then carried overland to the army's siege lines. To protect this supply route, the British constructed 4 earthwork redoubts on the adjacent Causeway Heights, and stationed Turkish infantry and artillery in each one.

The Battle of Balaclava was an indirect attempt by the Russians to relieve the siege. If they could overrun the heights and then recapture Balaclava harbor, they would cut the British army's supply line and make its position untenable (Ponting 2004: 123). The British would be forced to pull back, the siege would be lifted, and the allied campaign would collapse.

The initial Russian infantry assault quickly captured the redoubts, but subsequent advances were unsuccessful. Their main cavalry force was rebuffed by the British Heavy Brigade, despite being twice as numerous and better positioned (Adkin 1996: 108-112). A "thin red line" of infantry and cannon similarly repulsed a smaller Russian cavalry detachment (Adkin 1996: 103-104).

The British army commander was concerned by the loss of the redoubts and their cannon. Raglan had planned to send his 4th Infantry Division to retake the redoubts, but that unit had not yet reached the battlefield. He therefore dictated an order to the cavalry division through his chief of staff, General Airey: "Lord Raglan wishes the cavalry to advance rapidly to the front, and to try to prevent the enemy carrying away the guns. Troop of the Horse Artillery may accompany. French cavalry is on your left. Immediate, R. Airey." (Baumgart 1999: 129). This message was given to an aide, Captain Nolan, for delivery.

Nolan had minimal respect for officers who owed their rank to aristocratic lineage, and so made little effort to hide his contempt for Lucan, the cavalry division commander. When asked

by Lucan what guns the order was referring to, Nolan angrily replied "There my lord is your enemy! There are your guns!" as he gestured in the general direction of both the hilltop redoubts and the adjacent valley (Royle 2004: 273). Lucan consequently ordered his two cavalry brigades to charge the guns at the east end of the valley; he did not include the horse artillery troop (Royle 2004: 276).

As Cardigan's Light Brigade started its advance, it came under heavy Russian artillery fire from the valley to the east, from the Fedioukine Heights to the north, and from the Causeway Heights to the south. Scarlett's Heavy Brigade initially followed along in support, but Lucan halted their advance after seeing the intensity of the Russian fire.

The Light Brigade continued forward alone for 8 minutes across a mile-and-a-half of open terrain. Despite staggering losses, the unit reached the Russian position and overran the guns. But the survivors were too few to hold out against the nearby Russian cavalry, and after about 4 minutes of melee the British retreated back through the valley.

This withdrawal marked the end of the battle. The Russians claimed a victory, since they had captured and held the redoubts. Emboldened by this success, they launched a larger attack at Inkerman 11 days later to try to relieve Sevastopol more directly. That battle ended in a stalemate, however, and subsequently the Russian field army suspended activities for the winter.

For their part, the British had avoided outright defeat by retaining their supply port at Balaclava. But the loss of the redoubts restricted their flow of supplies between the port and the siege works (Ponting 2004: 137). This slowed the transport of food, clothing and fuel to the troops, and so aggravated their attrition during the ensuing winter.

By comparison, if the British had won the battle, the redoubts and roadway would have returned to their control, so that their supply line and winter attrition would have been less perilous. Furthermore, a twice-beaten Russian army might not have launched its later assault at Inkerman. Both of those factors would certainly have aided the Allies' efforts, and perhaps led to a faster end to the Sevastopol siege.

Counterfactual Research and Mathematical Models

This paper explores counterfactual histories that could have emerged if the British commanders had made different decisions. Historians have sometimes dismissed counterfactual analysis as little more than conjecture. In recent years, however, these analyses have become more common, in part because scholars like Tetlock and Belkin (1996) argue that we can learn interesting things about the actual past by exploring hypothetical alternatives to it. Hawthorne (1991: 158) suggests that examining potential pasts helps us to realize that the trajectory of history is not an inevitable one. Similarly, Ferguson (1998: 85) asks "How can we 'explain what happened and why' if we only look at what happened and never consider the alternatives?"

For example, consider the work of Tratteur and Virgilio (2003). They used an agent-based model computer simulation to study the reasons for the British victory at the 1805 Battle of Trafalgar. They first designed the model so that it would reproduce the results of the actual battle. They then varied several factors of interest, such as the wind direction and the British plan of attack, and measured the impacts on the battle's outcome. Their results indicate that if the British had employed a different plan, they still would have won the engagement, but with a greater loss of ships and crew. Thus while Nelson's bold attack was not essential to victory, it delivered that victory with a minimum of casualties.

Another way to model a battle is with mathematical equations, such as those developed by Frederick Lanchester (see, e.g., Taylor 1983). Lanchester equations provide a simple way to represent opposing forces that gradually wear each other down via attrition. They can model, e.g., melees among ancient swordsmen, or gunfire among modern riflemen, where each individual sword thrust or gunshot is just one of many. For example, Mackay and Price (2011) used such equations to examine Royal Air Force doctrine during the 1940 Battle of Britain, while Armstrong and Sodergren (2014) used them to study Pickett's Charge at the 1863 Battle of Gettysburg.

Lanchester equations are less suitable for battles with distinct waves of firepower, such as with airstrikes or missile salvos. For such situations, Hughes (1995) developed a set of equations called the salvo combat model. This model first adds-up the attacks being launched; e.g., the number of bomber aircraft sent on an airstrike. It then subtracts the number of interceptions made by the defender; e.g., by fighter aircraft on patrol. The resulting difference, if positive, indicates the number of attacks (e.g., bombers) that survive to hit their target. The loss inflicted on the defender is the sum of the damage caused by these hits.

Hughes' original salvo model is deterministic, in that it ignores random or unpredictable elements in the battle; e.g., it assumes that interceptions always succeed. Armstrong (2005) consequently developed a stochastic or probabilistic version of the model that allows for random variation in the success of each attack, the success of each interception, and the damage caused by each hit. This stochastic salvo model can be used to estimate the average and standard deviation of the losses suffered, as well as the probabilities of various outcomes.

For example, Armstrong and Powell (2005) used the stochastic model to examine decisions made by US Navy admirals leading up to the 1942 Battle of the Coral Sea. They calibrated the model using data about aircraft losses, bomb hits, etc., from the actual battle. Their results suggest that dispersing the American carriers into separate task forces would likely have reduced their losses. They also found that adding another American carrier would have greatly increased Japanese losses, but only slightly decreased American losses. A follow-up study (Armstrong 2014) found that being able to attack first, rather than simultaneously, would have been more valuable than an extra carrier.

In this paper we use salvo equations, rather than Lanchester equations, for two reasons. First, Lanchester equations model a battle as an ongoing and continuous flow of combat power,

whereas a cavalry charge is closer to being a single impulse. Second, Lanchester equations assume that both sides inflict casualties simultaneously, whereas cavalry only get to attack their targets after enduring defensive fire during their charge.

Our versions of the salvo model equations are simpler those than in Armstrong and Powell (2005) because we have no defensive interceptions to deal with. The equations were implemented in Excel software for convenience; copies of the spreadsheet are available upon request from the authors. (An earlier version of this study also used an agent-based model, and found that both approaches gave similar results; see Connors 2012).

The deterministic version of our model adds-up all of the "shots" (solid shot, exploding shell, canister, etc.) fired by Russian cannon during the British charge. It then sums the average loss per shot to get the total casualties inflicted. These are subtracted from the initial British strength to get the number of cavalry that survive the cannon fire and so can melee with the Russian forces.

$$Survivors = Initial - Casualties \qquad \text{where} \quad Casualties = \sum_{i=1}^{Shots} Loss_i$$

The probabilistic version of the model adds more details. It is logical to think of each artillery round as either hitting or missing its target; so every shot by the Russian artillery is given a probability p of hitting the British cavalry. The total number of hits (i.e., successful shots) is thus a binomially distributed random variable with mean $\mu_{Hits} = (p)(Shots)$ and variance $\sigma_{Hits}^2 = (p)(1 - p)(Shots)$. Similarly, the loss inflicted should also vary from hit to hit, rather than being constant; so the loss per hit is treated as an independent and identically distributed random variable with mean μ_{Loss} and variance σ_{Loss}^2. The parameters are chosen so that the average cavalry loss per artillery shot in the stochastic model equals the fixed loss per shot in the deterministic model; i.e., $(p)(\mu_{Loss}) = Loss_i$.

The total number of casualties suffered by the British during the charge therefore is the sum of a random number of random variables, and so is itself a random variable. The equations to calculate its mean and variance are well established (see, e.g., Armstrong 2005).

$$\mu_{Casualties} = \mu_{Hits}\mu_{Loss} \quad \text{and} \quad \sigma_{Casualties}^2 = \mu_{Hits}\sigma_{Loss}^2 + \mu_{Loss}^2\sigma_{Hits}^2$$

Since *Survivors = Initial – Casualties*, the variance of the British casualties is also the variance of their survivors. We use this variance to estimate 90% prediction intervals for the number of survivors; that is, if the battle were refought many times, only 5% of the time would the number of survivors lie below the lower limit of this range, and only 5% of the time would it be higher than the upper limit. The limits are calculated by assuming that the survivor distribution is approximately normal (as in, e.g., Armstrong and Powell 2005), so that ± 1.645 standard deviations will cover 90% of the outcomes.

$$Prediction\ interval = \mu_{Survivors} \pm 1.645\,\sigma_{Casualties}$$

This equation-based model is similar to discrete event computer simulations, such as agent based models, in that both models treat a battle's outcome as a random variable, and so both give estimates of its mean, variance, and probability distribution. Unlike computer simulations, however, our model does not contain any random elements itself. This means we do not need to "run" it multiple times to generate a sample of outcomes for each scenario, nor do we need to use inferential statistics to compare those samples.

Scenario 1: The Light Brigade Charges along the Valley

Our modeling begins with the historical attack, in which the Light Brigade charged the Russian cannon at the east end of the valley. The first step is to calibrate the model by estimating the equation parameters. The approach is analogous to using a weigh scale. One starts by weighing objects of known weight; this calibrates the scale, so that it can then be used to measure objects of unknown weight. In the present case, we ensure that the model reproduces the outcome of the actual battle, before applying it to the counterfactual scenarios.

The model's data are drawn from historical sources to the extent possible. We especially refer to Adkin (1996) because he provides detailed numerical estimates for many of our parameters; we are forced to rely on approximations for some of the remainder. The next sub-section describes these values.

Model Inputs

On the British side, Adkin (1996: 218) calculates that there were 664 horsemen who participated in the Light Brigade's charge; other sources give very similar numbers. Of these, only 195 reported back immediately after the charge; this means the brigade suffered 664 - 195 = 469 casualties. As in Armstrong and Powell (2005) and Hughes (1995), this figure includes all combatants knocked out of battle, not just those who died. (After stragglers trickled in, the brigade reported 298 men killed, wounded, or captured. Also lost were 302 horses; Adkin 1996: 218.) It is clear from historical accounts that most of the casualties occurred during the charge itself, rather than during the ensuing melee and retreat; but the exact division between the former and latter is unknown. As an approximation, we assume that all of the British casualties occurred during the charge itself. This is a conservative approach, in that the resulting formulas will slightly overestimate the effectiveness of the Russian guns.

We do not include any British cannon in our analysis. Although one troop of the Royal Horse Artillery was mentioned in Raglan's orders, it did not take part in the charge that Cardigan completed (Scenario 1), nor in the one that Lucan initially started (Scenario 2) (Royle 2004: 276). We consequently exclude it from the other counterfactual cases as well (Scenarios 3 and 4).

On the Russian side, the 1st Battery of the 16th Artillery Brigade was the first to fire at the charging British. They were set up on the Fedioukine Heights north of the valley. Adkin (1996: 139-143) estimates that their 10 guns fired about 7 times each (2 shots per minute for 3.5 minutes) into the flank of the Light Brigade as it passed, for a total of 70 shots. This battery next began firing at the Heavy Brigade's abortive advance, but stopped when attacked by the French Chasseurs d'Afrique (Adkins 1996: 165).

More flanking fire followed from the 7th Battery of the 12th Artillery Brigade, which was deployed near Redoubt 3 on the Causeway Heights south of the valley. Adkins (1996: 143-145) suggests their 8 guns fired about 4 rounds each as the British rode past, for a total of 32 shots.

The target of the charge was the 3rd Battery of the Don Cossacks Brigade, which was lined up across the east end of the valley. Adkin (1996: 145-151) estimates that each of their 8 guns would have fired about 11 shots head-on into the Light Brigade, for a total of 88 shots.

Table 1. Russian artillery data for Scenario 1, the historical charge

	Fedioukine Heights	Causeway Heights	Valley
Number of guns	10	8	8
Number of attacks per gun	7	4	11
Total shots	70	32	88

Based on Adkin's estimates, the Russian cannons fired a total of $70 + 32 + 88 = 190$ rounds (shot, shell, case, or canister), and inflicted 469 casualties. This implies that on average each round knocked out $469 / 190 = 2.4684$ soldiers. Some of these rounds would have missed the target, and the ones that did hit would have caused varying numbers of casualties. Since historical records do not precisely describe the results of most individual cannon shots, some assumptions in this regard are necessary. For now, we simply suppose that each round had a 50% chance of hitting. This implies that each successful hit would have inflicted an average loss of 4.9368 soldiers, as then $4.9368 \times 0.50 = 2.4684$. Finally, we set the standard deviation of the loss per hit at one-third of the average, i.e., $4.9368 / 3 = 1.6456$ soldiers, as in Armstrong and Powell (2005).

Any cavalry that survive the charge will be able to attack the Russian gunners with their sabers and lances, but we will not calculate the resulting gunner casualties here, as historical sources do not detail them. The reports do make it clear that the entire battery was at least temporarily overrun. "Scarce a man escaped, except those that crept under their gun carriages, and thus put themselves out of reach of our men's swords" (Calthorpe 1980: 77).

We also need to account for the Russian cavalry force located behind the guns in the valley. These are not included in the model's calculations, because again the battle accounts do not provide much information about their casualties. Instead, their numbers will provide important context when interpreting the model outputs. General Rijov had 14 squadrons of

Hussars (regular light cavalry) and 6 of Cossacks (irregular light cavalry) in his main force. These 20 squadrons had an estimated 2000 men at the beginning of the day (Adkin 1996: 81-82), but lost about 240 during an initial skirmish with the Heavy Brigade (Ponting 2004: 129). This force was then reinforced by 4 additional squadrons of Cossacks (Adkin 1996: 141). Thus some (2000 - 240 + 400) = 2160 Russian cavalry were present behind their gun line when the Light Brigade charged.

Model Outputs

Our equations use this data to estimate the effect of the Russian cannon fire on the British cavalry. Given that the artillery is firing *Shots* = 190, each of which causes *Loss* = 2.4684 men, the deterministic model calculates British casualties at 190 x 2.4684 = 469 men. In the probabilistic model with p = 50% chance of hitting, the number of successful hits has average μ_{Hits} = 190 x 0.50 = 95 and standard deviation σ_{Hits} = (190 x 0.50 x (1 – 0.50))$^{1/2}$ = 6.892. The total casualties inflicted therefore has average $\mu_{Casualties}$ = 95 x 4.9368 = 469 men and standard deviation $\sigma_{Casualties}$ = (95 x 1.6456^2 + 4.9368^2 6.892^2)$^{1/2}$ = 37.6 men.

The first column of numbers in Table 2 summarizes the final results. The model estimates that an average of $\mu_{Survivors}$ = 554 – 469 = 195 soldiers survive to reach the Russian guns. This naturally matches the historical outcome, because we specifically calibrated the inputs to reproduce that outcome.

**Table 2.** Model inputs and outputs by scenario

	Light v. Valley	Both v. Valley	Light v. Heights	Both v. Heights
Russian cavalry & infantry	2160	2160	4400	4400
Russian artillery shots	190	232	226	286
British initial cavalry	664	1367	664	1367
British casualties average	469	573	558	706
British survivors average	195	794	106	661
Ratio Russians/British	11.1	2.7	41.5	6.7
Casualty 90% interval	407-531	504-642	491-627	630-782
Survivor 90% interval	133-257	726-863	37-173	585-737
Standard deviation	37.6	41.6	41.0	46.2

Beyond these averages, the stochastic version of the model also gives a rough estimate of the potential variability of the outcome. That is, if the charge were re-fought many times the same way, how widely could we expect the outcomes to vary? Table 2 shows that about 90% of the time, the number of surviving British cavalry would fall between 133 and 257. That is, only 5% of the time would fewer than 133 survive, and likewise only 5% of the time would more than 257 survive. Figure 1 is a histogram that illustrates this potential variation.

On the one hand, these estimates of potential variation show that the casualty counts could have differed noticeably from the historical figures simply by luck. On the other hand, those differences are too small to have made any meaningful difference in the overall outcome of the charge.

Figure 1.

Distribution of British cavalry who survive to reach the guns in Scenario 1, the historical charge along the valley
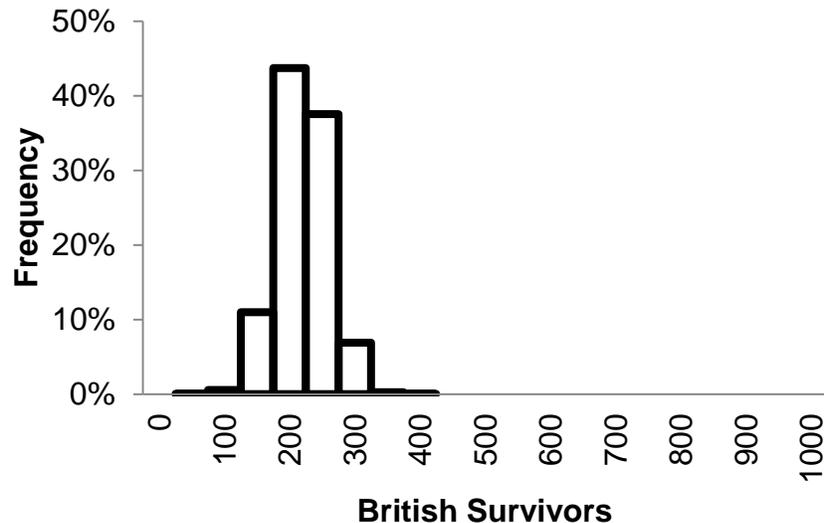
Implications

The Russian cavalry are not included within the model itself, so we need to deal with them qualitatively. There is ample evidence to indicate that these units lacked an appetite for fighting. Earlier in the battle, the Heavy Brigade had driven-back Rijov's lighter cavalry despite being outnumbered at least 2-to-1 and having to fight uphill (Adkin 1996: 108-112), while another detachment's charge had been repulsed by the 93rd Highland Regiment. Battle accounts also indicate that in the face of the Light Brigade's bold charge, the Russian cavalry initially started to withdraw: "A number of Rijov's units were in a state of near panic" (Adkin 1996: 193). This was especially the case for the Cossack horsemen (about 40% of the force), who as irregulars were not accustomed to fighting formed units. "... the Cossacks, frightened by the disciplined order of the mass of cavalry bearing down on them, did not hold, but, wheeling to their left, began to fire on their own troops in their efforts to clear a route of escape ..." (Adkin 1996: 179).

However, the Russians regained their composure once they realized how few British remained. The former outnumbered the latter 2160 to 195, or about 11-to-1. Even if the British had been lucky enough to have 257 survivors (i.e., the upper end of the 90% prediction interval) they would still have been outnumbered more than 8-to-1. Regardless of their relative fortune

when traversing the Russian cannon fire, the Light Brigade survivors would have been overwhelmed by the Russian horsemen.

Scenario 2: The Light and Heavy Charge along the Valley

Next we use the calibrated model to analyze a counterfactual scenario in which the Heavy Brigade joins the Light in a combined charge along the valley. The historical attack actually started this way, but then Lucan changed his mind. As Adkin (1996: 171) commented, "It remains one of those fascinating 'ifs' of military history": what if the Heavy Brigade had carried-through with the charge?

Model Inputs

To model this situation, we add cavalry for the British and cannon volleys for the Russians. The Heavy Brigade started the day with about 800 soldiers, but suffered 97 casualties in an initial skirmish with the Russian cavalry (Adkin 1996: 172). So the British gain 703 more cavalry, roughly doubling their total to 1367.

With twice as many British units passing sequentially through the valley, the Russian battery on the Causeway Heights would have had twice as many opportunities to fire; hence we double its volleys from 4 to 8. We also increase the shots by the Fedioukine Heights battery, but only by 1 volley, from 7 to 8. Those guns had just begun firing at the Heavy Brigade in the actual battle, but then were silenced by the French cavalry. We leave the battery in the valley unchanged, as its field of fire was already filled with Light Brigade targets. This gives the Russian artillery a new total of 190 + (8 x 4) + (10 x 1) = 232 shots, or about 22% more than in the historical case. We assume that while the overall quantity of Russian fire increases, the quality (lethality) of it remains roughly similar; e.g., the cannon continue to fire a similar mix of solid shot and canister, at similar ranges and angles of deflection.

Model Outputs

The outputs from the adjusted model are summarized in the second column of numbers in Table 2. British average casualties increase by 104 relative to the historical base case, while the survivors jump to 794. So when twice as many soldiers start the charge, about 4 times as many complete it. Figure 2 shows the frequency distribution.

Implications

This scenario is the one where it seems most plausible that the British could have pushed the Russians off the field. Though they are still outnumbered, the odds are much closer than before, about 2.7-to-1. Furthermore, the Russian cavalry at Balaclava had demonstrated an unwillingness to fight directly against the British soldiers; this may have been due to their lighter horses, their irregular training, or simply a reluctance to face opponents who were not already retreating. Recall that many of the Russian cavalry had begun withdrawing in the face of the

Light Brigade's actual charge; it should not have taken much more to keep them going. Recall as well that the Heavy Brigade had repulsed Rijov's cavalry in an earlier skirmish while outnumbered 2-to-1 and badly positioned. It therefore does not seem far-fetched to think that the combined brigades could have won when outnumbered 2.7-to-1 and aided by the momentum of their charge.

Figure 2.
Distribution of British cavalry who survive to reach the guns in Scenario 2,
a joint charge along the valley
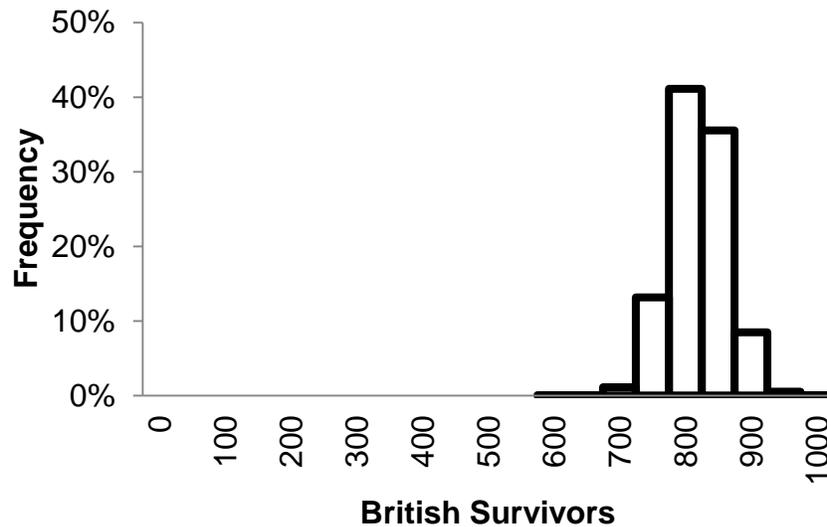
The resulting British position at the east end of the valley would have been tenuous. But with their center broken, the Russian position would have been even more tenuous.

Scenario 3: The Light Brigade Charges the Heights

After the actual charge, Raglan claimed that the guns on the Causeway Heights had been his intended objective for the cavalry charge, and that Lucan had blundered by charging down the valley instead. Lucan conversely blamed Raglan for issuing vague orders, and a public controversy ensued (Palmer 1997: 132). Thus the next counterfactual scenario supposes that the Light Brigade (alone) charges the Russian battery on the Causeway Heights, rather than the one in the valley. Given the controversy, this scenario is highly plausible and of significant historical interest.

Model Inputs

Redoubt #3 was the closest earthwork that was still Russian-held at the time of the charge. It stood on the Causeway Heights about 405 feet above the valley floor (Robins 1997: 89). To reach the Russian battery near that redoubt, the British cavalry initially would have

12

headed east along the valley as in the actual charge, but then would have needed to veer southeast (Adkin 1996: 141).

Since this scenario only involves the Light Brigade, the British cavalry strength is set at 664, as in the historical case. On the Russian side, we can assume the cannon on the Fedioukine Heights fire 7 volleys as in the historical case; but the other 2 batteries need adjusting. First, we "swap" their firing rates to reflect their exchanged roles. That is, the guns on the Causeway Heights start with 11 volleys instead of 4, because they are now the charge's target; and the guns in the valley start with 4 volleys instead of 11, as they are now on the flank.

Second, we account for the final stage of the charge being uphill: the British horses would necessarily have slowed down, giving the Russian guns more time to fire. For now we assume that both batteries have time to fire 1 additional volley. Thus the cannon in the valley now shoot 4 + 1 = 5 times each, while those on the Causeway Heights shoot 11 + 1 = 12 times.

The Russians also had 4 battalions of the 24th Odessa infantry regiment deployed near the redoubt. When the historic charge commenced, these battalions adopted defensive square formations that made them largely impervious to unsupported cavalry attacks (Bogdanovich 1877: appendix pages 8-19). The infantry were armed with muzzle-loading smoothbore muskets, and were only able to fire only about once per minute (Adkins 1996: 82). To reflect this, we give them 5 volleys of fire: 1 as the cavalry approach, plus 4 more during the ensuing melee around the cannon. (We assume that the melee lasts about 4 minutes, just as in the historic charge.) Presumably only one side of each square would have faced the British at any given time; i.e., about 250 men per square. Depending on the depth of the square formation, perhaps half of those soldiers (i.e., 125) would have been able to fire.

But how effective would that fire have been? In particular, how many infantry muskets should we equate to 1 cannon in the context of the model? Against targets within musket range, i.e., 200 yards or less, cannon would generally fire canister shot that functioned like giant shotgun shells. The metal balls within each canister would spread out to saturate an area about 20 yards wide at 200 yards (Adkins 1996: 151). One example of canister shot from this era contained 112 projectiles, each with about the same shape and weight as a musket ball (Rothenberg 1981: 78). This suggests a simple approximation: that each side of an infantry square (about 125 muskets firing) inflicts roughly the same casualties as 1 cannon. Thus we treat the 4 infantry battalions as being equivalent to 4 short-range cannons. This is obviously a very rough approximation, so later we will explore its influence. Adding the muskets to the artillery gives total Russian fire equivalent to 10 x 7 + 8 x 5 + 8 x 12 + 4 x 5 = 226 shots.

Finally, there were also 4 squadrons (about 400 men) of Russian cavalry on the heights: lancers from the Uhlan Regiment, (Adkin, 1996: 81-82 and 141).

Model Outputs

The third column in Table 2 shows this scenario's results. On average the British suffer 89 extra casualties, or 19% more than in the historical case. Only 106 soldiers reach the Russian positions, 46% less than in the actual charge.

Implications

These calculations indicate that a charge by the Light Brigade against the heights would have been led to higher British losses than the actual charge along the valley. While the survivors may have been able to overrun the cannon there, they then would have faced a combined force of cavalry and infantry that outnumbered them 41.5-to-1. A British defeat would have been all but certain.

Scenario 4: The Light and Heavy Charge the Heights

The previous scenario reflects Raglan's intent for a charge against the Causeway Heights. It is probable that he furthermore had wanted both cavalry brigades involved. Our final scenario therefore models this combined charge.

Model Inputs

This scenario combines elements from the two previous ones. We set the British cavalry force at 1367, as in Scenario 2, to represent the Heavy Brigade's addition. We give the Fedioukine Heights battery 8 volleys, as in Scenario 2, and the Causeway Heights battery 12 volleys, as in Scenario 3. For the battery in the valley, we start with 5 volleys as in Scenario 3, and then double this to 10 to reflect the Heavy Brigade's presence, similar to Scenario 2. We likewise double the participation by the infantry (2 sides of each square firing), and so count the 4 battalions as equivalent to 8 short-range cannons. Thus the Russian fire is now equivalent to $10 \times 7 + 8 \times 12 + 8 \times 10 + 8 \times 5 = 286$ shots.

Model Outputs

The last column of Table 2 shows that this scenario yields the heaviest British losses, averaging 706 soldiers. This is 51% more than the historical case.

Implications

With 661 cavalry reaching the heights in this scenario, the British could certainly have overrun the enemy guns there, and might have dispersed the Russian cavalry as well. Even so, there would still have been 4000 infantry in square formation continuing to fire at them. It therefore seems doubtful that the British would have been able to remain on the heights.

Sensitivity Analysis for Scenarios 3 and 4

This study obviously contains many assumptions and approximations. One of roughest ones concerns the extra Russian firepower in Scenarios 3 and 4 during a British charge up the heights. One way to evaluate whether the accuracy of this approximation matters is to repeat the analysis using two alternative sets of values: a "low firepower" version and a "high firepower" version.

For the high firepower version of Scenario 3, we let the cannons fire 2 extra volleys due to the uphill charge instead of 1, and count each infantry battalion as 1.5 cannons instead of 1; the total shots become 10 x 7 + 8 x 6 + 8 x 13 + 6 x 5 = 252. In the low firepower version, the cannons fire no extra volleys, and each battalion counts as only 0.5 cannons; the total shots become 200.

Similarly for Scenario 4, with high firepower the cannons fire 2 extra times, and each battalion counts as 3 cannons, for a total of 330 shots. With low firepower, the cannons fire no extra volleys, and each battalion counts as 1 cannon, for a total of 242 shots.

Another assumption open to question is the probability p that each cannon round effectively hits its target. We originally had set $p = 50\%$, the midpoint of its possible range between 0% and 100%. This assumption has no impact on the average losses, but it does affect the standard deviations and prediction intervals. We therefore now try two other values. The high probability version assumes $p = 75\%$; to keep the average casualties constant, the average loss per hit is reset to 3.2912 soldiers. Similarly, the low probability version assumes $p = 25\%$ and an average loss per hit of 9.8736 soldiers.

The impact of these alternatives for Scenario 4 is shown in Table 3. The center column of numbers repeats the original results for the scenario, while the adjacent columns display the results of the low and high firepower alternatives. The bottom six rows show the impact of the different hit probabilities.

Table 3. Sensitivity analysis for Scenario 4, the joint charge against the heights

	Low Firepower	Original Firepower	High Firepower
Russian artillery shots	242	286	330
British casualties average	597	706	815
British survivors average	770	661	552
Ratio Russians/British	5.7	6.7	8.0
Survivor standard deviation, $p = 75\%$	26.6	29.0	31.1
Survivor 90% interval	726-814	613-709	501-604
Survivor standard deviation, $p = 50\%$	42.5	46.2	49.6
Survivor 90% interval	700-840	585-737	471-634
Survivor standard deviation, $p = 25\%$	71.3	77.5	83.2
Survivor 90% interval	652-887	534-789	416-689

The average number of British survivors varies up or down by 109 cavalry as the Russian firepower is decreased or increased, respectively. We think these differences are too small to alter our overall conclusions for the scenario. The impact for Scenario 3 (not shown) is smaller.

Similarly, the standard deviations of the survivors increase or decrease if the hit probability is set lower or higher, respectively. This in turn widens or narrows the 90% prediction intervals, but not enough to affect our conclusions.

Discussion

Implications of the Scenarios

A counterfactual experiment like this cannot prove anything definitively. However, we believe it offers quantitative support for four propositions.

First, the actual charge (Scenario 1) had no meaningful chance of success. Even if the Russian gunners had had significantly less luck with their shooting, there would have been too few British survivors to defeat the Russian cavalry.

Second, all of the alternative charges (Scenarios 2, 3, and 4) would have led to higher British casualties; about 19% to 51% higher by our estimates. After the actual battle, the British leaders were severely criticized for the high losses. The *London Times* carried the battle's story on 9 November 1854 (Hibbert 1961: 158), and Lucan was subsequently recalled to London to answer for his role in the charge. If the casualties had been higher, with no victory to justify them, the public outcry and political pressure would have been greater. From this perspective, the charge implemented by Lucan along the valley using only the Light Brigade was the "least worst" of the four options. Of course, there would have been no casualties at all if Raglan had not ordered the charge.

Third, it follows that if the charge had instead been directed against the heights, as Raglan had wanted, the results would likely have been worse for the British than the historical ones. A charge by just the Light Brigade (Scenario 3) would certainly have led to more casualties and less chance of success, given the 41-to-1 odds against the British survivors. Scenario 4's combined charge by both brigades would have put more British cavalry on the heights, but they still would have been outnumbered more than 6-to-1, and would have suffered the highest casualties in getting there.

Fourth, the alternative with the best chance of success was a combined charge by both brigades along the valley (Scenario 2). This would have placed the most British horsemen into action, with the least odds against them, to fight the enemy that they had the best chance of defeating.

Thus ironically, the best alternative is the one that Lucan had initially and reluctantly ordered; but it is neither the one that he carried out, nor the one that Raglan had intended. It

16

seems Cardigan was right to complain that his advance should have been supported by the Heavy Brigade. The chances of British victory may have been uncertain with that support, but they were non-existent without it.

A successful joint charge could have turned Balaclava into a British victory, albeit a bloody one. Faced with the loss of their center to British cavalry, and the eventual advance on their left by British infantry, the Russians might have been compelled to withdraw from the Causeway Heights. This would have allowed the British to better supply their siege lines during the following winter. It may also have discouraged the Russians from attacking at Inkermann. Both outcomes would have strengthened the allied operation, and perhaps thereby have hastened the capture of Sevastopol and the end of the war.

Strengths and Limitations of the Methodology

The salvo combat model has previously been applied to study 20th century naval engagements, such as the Battle of the Coral Sea (Armstrong and Powell 2005). We believe it also has been useful here for studying a 19th century land battle, but it does have some limitations.

One is that salvo models, like their Lanchester equivalents, are best suited to relatively simple battles. They approximate combat that features a single pulse of combat power, as with the airstrikes in Armstrong and Powell (2005). But they would not fit complex engagements where many heterogeneous units act independently. Thus situations like the Battle of Trafalgar are better studied using tools like agent based modeling, as in Tratteur and Virgilio (2003).

Another limitation is that salvo models, like other calculations, generate outputs that are only as good as their inputs. For Balaclava, historical accounts provide detailed data for the British, but not for the Russians. Thus we should not put too much weight on the specific numerical values that the model generates; these might best be viewed as "engineering approximations".

Nonetheless, a quantitative model like ours does offer the benefit of a precise and logical structure that explicitly shows the data and assumptions being used. Scholarly opinions informed by reasoned calculations are arguably better than scholarly opinions alone. At the very least, the relative simplicity of our model allows other researchers to easily modify the study to experiment with different parameter values. For example, someone who questions one of our assumptions can input their own data into the equations and quickly see whether that change makes any significant difference in the results.

Acknowledgements

References

Adkin, M. 1996. *The Charge: The Real Reason Why The Light Brigade Was Lost*. Barnsley: Pen and Sword Books Ltd.

Armstrong, M.J. 2014. The salvo combat model with a sequential exchange of fire. *Journal of the Operational Research Society* 65 #10: 1593-1601.

Armstrong, M.J. 2005. A stochastic salvo model for naval surface combat. *Operations Research* 53 #5: 830-841.

Armstrong, M.J., and Sodergren, S.E. 2014. Refighting Pickett's Charge. Working paper, Department of History, Norwich University, Northfield. Under review at *Social Sciences Quarterly*.

Armstrong, M.J., and M.B. Powell. 2005. A stochastic salvo model analysis of the Battle of the Coral Sea. *Military Operations Research* 10 #4: 27-37.

Baumgart, W. 1999. *The Crimean War: 1853-1856*. London: Oxford University Press.

Bogdanovich, Lt. General M.I. 1877. Organization, tactics and weapons of the Russian Army. In *Vostochnaya Voina 1853-1856 godov,* 2nd ed., vol. 1. Edited by A.M. Zaionchkovsky. St. Petersburg: Poligon.

Calthorpe, S.J.D. 1980. *Cadogan's Crimea*. New York: Atheneum.

Connors, D. 2012. *Into the Valley of Death Rode the Digital Six Hundred*. Major research paper, Department of History, Brock University, St Catharines.

Ferguson, N. 1998. *Virtual History: Alternatives and Counterfactuals.* London: Papermac.

Hawthorne, G. 1991. *Plausible Worlds: Possibility and Understanding in history and the Social Sciences.* Cambridge: Cambridge University Press.

Hibbert, C. 1961. *The Destruction of Lord Raglan: A Tragedy of the Crimean War 1854-55.* Boston: Little, Brown & Co.

Hughes, W.P. 1995. A salvo model of warships in missile combat used to evaluate their staying power. *Naval Research Logistics* 42: 267-289.

Kagan, F. 2002. Russia's Small Wars. In *The Military History of Tsarist Russia.* Edited by F. Kagan and R. Higham. Hampshire: Palgrave.

Mackay, N. and C. Price. 2011. Safety in Numbers: Ideas of Concentration in Royal Air Force Fighter Defence from Lanchester to the Battle of Britain. *History* 96: 304–325.

Palmer, A. 1987. *The Banner of Battle: The Story of the Crimean War*. London: Weidenfeld and Nicolson.

Ponting, C. 2004. *The Crimean War: The Truth Behind the Myth*. London: Chatto and Windus.

Robins, C. 1997. Lucan, Cardigan and Raglan's Order. *Journal of the Society for Army Historical Research* 75 #2: 86-92.

Rothenberg, G.E. 1981. *The Art of Warfare in the Age of Napoleon.* Bloomington: Indiana University Press.

Royle, T. 2004. *Crimea: The Great Crimean War, 1854-1856*. Basingstoke: Palgrave Macmillan.

Taylor, J.G. 1983. *Lanchester Models of Warfare*. Catonsville: Operations Research Society of America.

Tetlock, P.E. and A. Belkin, editors. 1996. *Counterfactual Thought Experiments in World Politics: Logical, Methodological and Psychological Perspectives.* Princeton: Princeton University Press.

Tratteur, G., and R. Virgilio. 2003. An agent based computational model for the battle of Trafalgar. *WETICE '03 Proceedings of the Twelfth International Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises*: 377-382.